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THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

Vol. 54 JULY, 1945 No. 1

INFANTILE CORTICAL HYPEROSTOSES

PRELIMINARY REPORT ON A NEW SYNDROME*

By JOHN CAFFEY, M.D., *and* WILLIAM A. SILVERMAN, M.D.
NEW YORK, NEW YORK

IN 1939, one of us (J.C.) described the case of an infant with multiple cortical hyperostoses scattered in the tubular bones of the extremities and the ribs and clavicles whose clinical and laboratory findings did not seem to be consonant with any recorded disease.[3] The causal agent of the disorder was not determined but it was clear that the patient suffered neither from scurvy nor syphilis, infantile diseases in which multiple cortical thickenings are commonly found.

Since that time we have studied 3 additional patients with similar manifestations whose combined clinical and roentgen findings appear to constitute a new infantile syndrome. The principal features of the disorder include: onset in the early part of the first year; tender swellings in one or more of these sites—face and jaws, scapular regions, and extremities; and multiple scattered hyperostoses demonstrated roentgenographically in bones adjacent to the tender swellings and also in several other bones whose overlying soft tissues appear to be normal, clinically and roentgenographically.

CASE REPORTS

CASE 1 (B.H. No. 547,799). The patient, a male infant, was born on February 12, 1938. The mother had enjoyed normal health during the pregnancy and apparently had eaten foods which contained adequate vitamins. Delivery was spontaneous; birth weight was 3.2 kilograms. During the first ten days he sucked at the breast and thereafter received a variety of formulas made from whole milk, Biolac or evaporated milk. Orange juice, 10 drops daily, was begun during the fourth week and was gradually increased until the seventh week, after which he received 1 tablespoonful daily. Hot water was often added to the orange juice and much of the juice was said to have been vomited. Oleum percomorphum, 5 drops daily, was given from the fourth to the ninth week and Drisdol, 3 drops daily, from the ninth to the twelfth week.

The infant thrived until the seventh week when he became hyperirritable and feverish; thereafter he lost his appetite, failed to gain and cried out when the left leg was handled. A few days after the onset of hyperirritability and fever, both legs became tender and the lower extremities showed little spontaneous movement. Moderate fever persisted until hospital admission, reaching a level of 101°F.

* From the Pediatric Department, College of Physicians and Surgeons, Columbia University and the Babies Hospital, New York. Read in summary before the Pediatric Section of the New York Academy of Medicine, March 8, 1945.

daily. Four days before admission the left leg became visibly swollen. Swellings were not recognized in the cheeks or jaws.

In the physical examination made at admission when the infant was twelve weeks

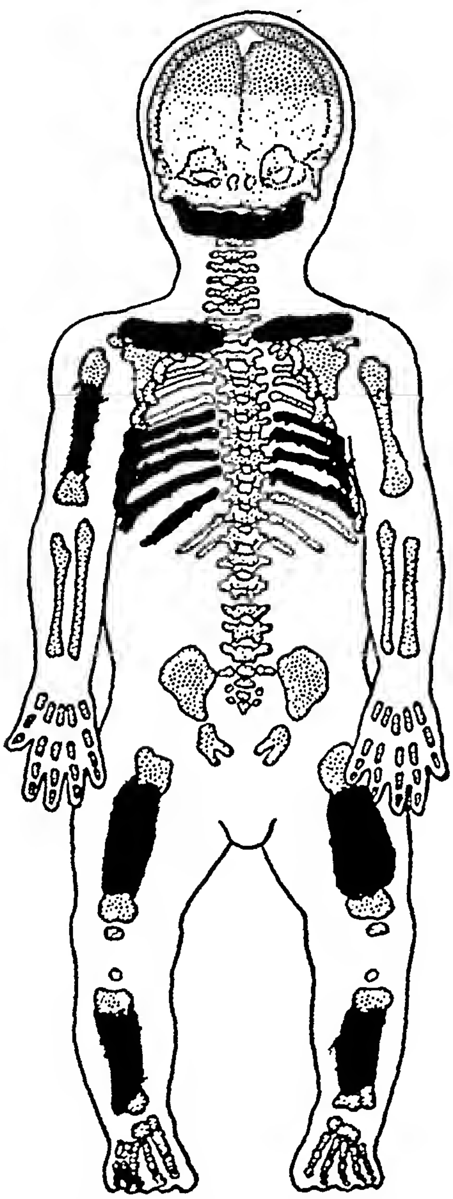
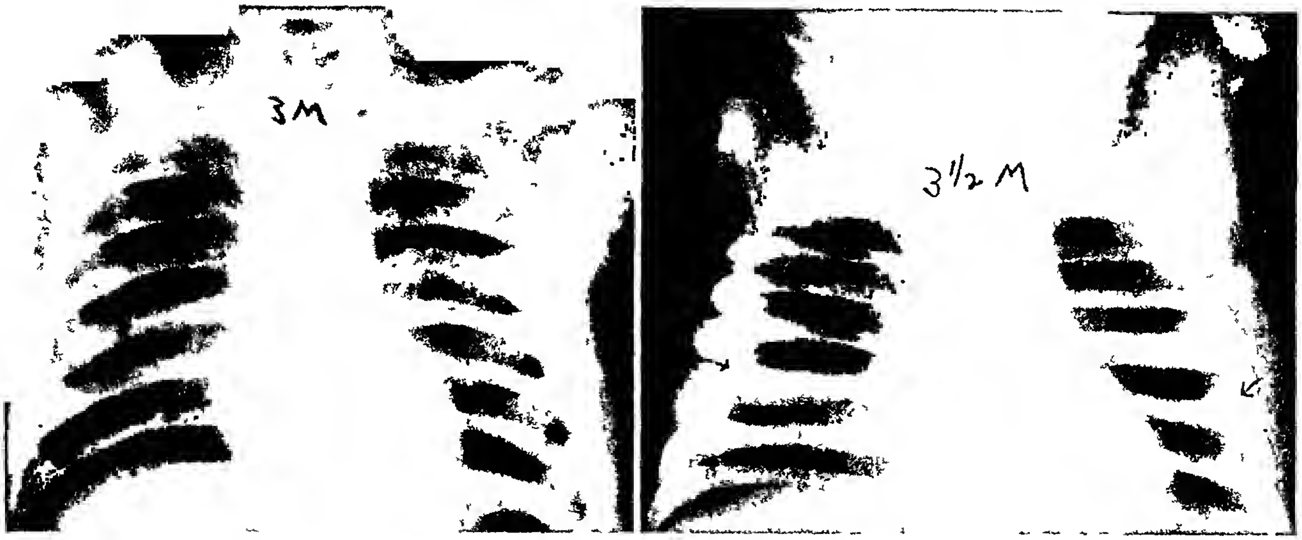


FIG. 1. Case 1. Spot map of the skeleton in which the heavily shaded bones are the sites of hyperostoses. The most marked changes are located in the clavicles and femurs. The epiphyseal ossification centers and the round bones are not affected.

of age, the temperature was found to be normal and he did not appear to be ill. The extremities moved freely. The swelling of the left thigh was still visible but was not tender and showed no signs of inflammation. There were no hemorrhages in the conjunctivae or mouth. The lower pole of the spleen was palpable. The multiple skeletal thickenings revealed later by roentgen examination were not recognized in the first physical examination. The Mantoux test gave a negative reaction.

The Kahn test for syphilis was negative on the infant's blood and cerebrospinal fluid and on the mother's blood. The number of red blood cells and the hemoglobin content were normal, 4.7 million per cu. mm. and 71 per cent respectively; in several examinations the average leukocyte count was 13,000 per cu. mm. and the polymorphonuclears varied between 15 and 57 per hundred, the lymphocytes between 40 and 84 per hundred and the monocytes between 1 and 8 per hundred. The bleeding and clotting times were normal; the blood platelets averaged 600,000 per cu. mm. Determinations of ascorbic

FIG. 2. Case 1. Roentgenogram of the lower extremities at fourteen weeks of age. Massive irregular cortical thickenings are visible in both tibias and the left femur; their external margins are irregular. A smaller smooth hyperostosis covers the right femur. The cortex in the terminal segments of the shafts, however, is not thickened and the metaphyses show no changes suggestive of scurvy. There are no scorbutic changes in the epiphyseal ossification centers. The soft parts of the left thigh are thickened. The overlying subcutaneous fat, however, is not involved.



A B

Fig. 3. Case 1. Roentgenograms of the thorax; *A*, at twelve weeks of age; *B*, at fourteen weeks. In *A* thick hyperostoses surround the clavicles; also several ribs on both sides are thickened and sclerotic. There is, however, no roentgen evidence of pleural exudate at this time. In *B* the pleuras are thickened on both sides. The liquid removed from the right pleural space contained 500 monocytes per cu. mm.; no bacteria were found in smears or cultures.

acid disclosed low concentrations in the blood and high concentrations in the urine. The excretion of large amounts of ascorbic acid in the urine was interpreted to be inconsistent with active scurvy. Tests for heterophile antibodies in the blood resulted in negative reactions as did agglutination tests for the typhoid-dysentery group of bacteria (Shiga, Flexner, Sonne, paratyphoid A and B), and for *B. melitensis* and *B. abortus*. Samples of blood cultured in aerobic and anaerobic media yielded no bacterial growth. In several examinations the sedimentation rate of the erythrocytes varied from 33 to 99 mm. during one hour.

The blood serum contained normal quantities of calcium and phosphorus. The serum albumin and globulin were present in normal amounts and in normal proportions. There was 164.3 mg. of total cholesterol in 100 cc. of blood; the cholesterol ratio (ester-free) was 2.12. Resistance of red blood cells to salt solutions was normal.

The urine was normal in four examinations. Occasional erythrocytes were found in the microscopic examinations but there was no significant hematuria.

Pathogens were not recovered in cultures of the feces and five guaiac tests for blood resulted in negative reactions.

Roentgenographic examination of the skeleton disclosed scattered hyperostoses in several bones (Fig. 1): in the mandible, both clavicles, the right humerus, several ribs, both femurs and both tibias. The most conspicuous changes were found in the femurs, which were surrounded by considerable soft tissue swelling (Fig. 2). There were no changes suggestive of

Fig. 4. Case 1. A more detailed view of the costal and pleural changes in Figure 3*B*. The costal thickenings are most pronounced in the lateral arcs but the posterior segments are also thickened.

Fig. 5. Case II. Photograph of the face at six months of age—four months after the first appearance of the facial swellings. The right cheek and the right side of the jaw are swollen.

scurvy in the metaphyses or the ossification centers in the epiphyses.

The patient remained in the hospital for four weeks. During the second hospital week when the infant was fourteen weeks of age and seven weeks after the appearance of the initial symptoms, pleural exudate appeared in both pleural spaces (Fig. 3 and 4). The pleural fluid which was removed from the right pleural space contained 500 monocytes per cubic millimeter; no bacteria were found in direct smears or cultures of this liquid. Fever accompanied the appearance of pleuritis; the temperature increased daily to levels of 100 or 101° F., during the interval between the tenth and twenty-third hospital days, after which the fever subsided and did not recur.

A piece of the thickened right clavicle was removed during the third hospital week. Microscopic examination disclosed only hyperplasia of normal lamellar bone. There was no evidence of old or recent inflammatory exudate or subperiosteal hemorrhage.

The course of the disease was benign after the patient came under our observation. Save for the development of monocytic pleuritis and its concurrent short febrile episode, there were no new active clinical manifestations. The swelling of the left thigh subsided gradually and never showed signs of suppuration. The infant was free from symptoms when he left the hospital at sixteen weeks of age and has remained asymptomatic. The Kahn test for syphilis was repeated at five months of age and resulted in a non-syphilitic reaction. At this time the bone lesions were still visible roentgenographically but showed distinct improvement in comparison with the earlier findings. In an examination made when the patient was six years, eight months of age he was normal clinically and his skeleton appeared to be normal roentgenographically.

Case II (B.H. No. 591,351). The patient, a male infant, was born on May 3, 1939, after cesarean section. He weighed 4 kilograms at birth. The pregnancy was uneventful and the maternal diet during gestation had apparently been adequate. Blood tests on both parents gave non-syphilitic reactions. The infant was healthy and developed normally during the

Fig. 6. Case II. Photograph of the right forearm at six months of age—three months after the onset of tenderness and swelling of the forearms. The right forearm is diffusely swollen and the fullness of the right cheek is evident.

first two months. Orange juice was added to the diet at the end of the first month; 1 to 3 ounces had been taken daily. Cod liver oil was given daily after the third month. Ascorbic acid and viosterol were given after the onset of symptoms in daily dosages of 100 mg. and 15 drops respectively.

During the eighth week, tender swellings appeared in both cheeks and both sides of the jaw and a low grade fever developed. The family physician suspected that the patient was suffering from bilateral parotitis. The swellings and fever persisted. During the twelfth week the temperature increased, reaching levels of 101 to 103°F. daily; at the same time the swellings of the cheeks enlarged, extending upward as far as the orbits. After admission to another hospital, the fever continued for several days when it suddenly subsided and simultaneously the facial swellings began to diminish. Roentgenograms of the jaw were interpreted as normal and Kline's test on the blood gave a nonsyphilitic reaction.

During the seventeenth week of life tender swelling of the right side of the face recurred and both forearms became extensively swollen and tender. At readmission to the same other

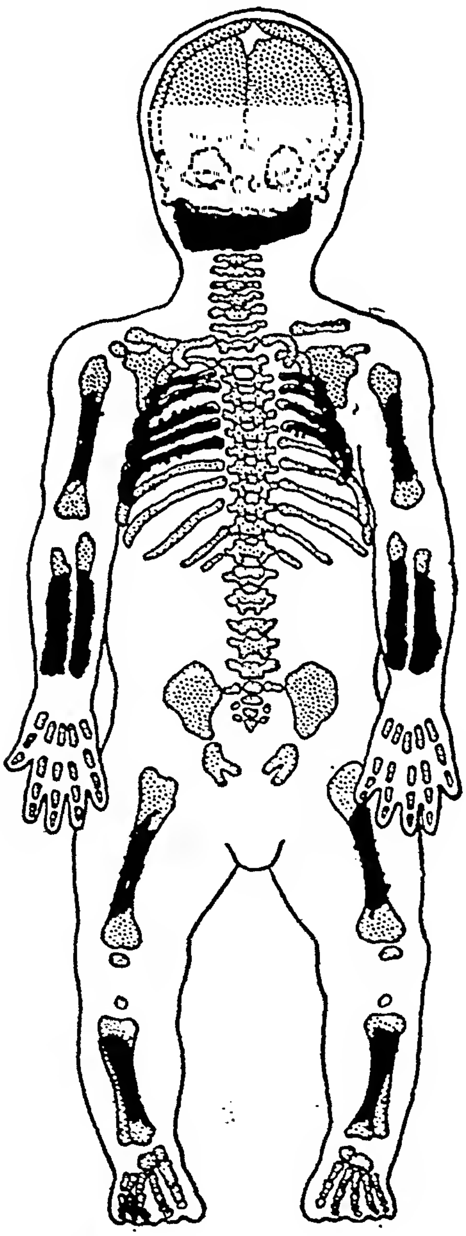


Fig. 7. Case II. Spot map of the skeleton in which the heavily shaded bones are the sites of cortical thickenings. In contrast to Case I, the clavicles are not affected and the forearms are the site of the largest hyperostoses in the extremities.

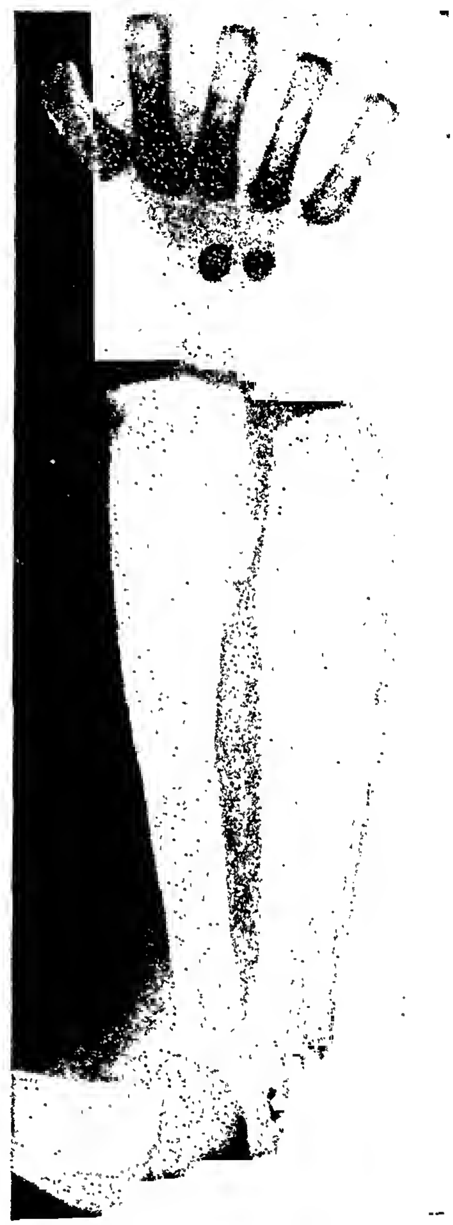


Fig. 8. Case II. Massive cortical thickenings of the right radius and ulna at five months of age; the bones of the hand are not involved. The absence of metaphyseal changes suggestive of scurvy is noteworthy. Similar changes were found in the left forearm.

Fig. 9. Case II. Lateral roentgenogram of the mandible at four months of age, two months after the first appearance of facial swelling. The mandible is diffusely thickened and is sclerotic. There is no evidence of bone destruction.

hospital, the only abnormal clinical findings were the aforementioned swellings which showed no increase in local heat, no hyperemia and no evidence of subcutaneous hemorrhage. The temperature at this time was normal. A Rumpel-Leede test for capillary fragility gave a normal reaction. The urinary findings were normal; there was neither gross nor microscopic hematuria. The erythrocytes were decreased to 2.2 million per cu. mm.; the hemoglobin measured 63 per cent. The leukocytes numbered 6,000 per cu. mm.; 51 per hundred were polymorphonuclears. Serum calcium, serum phosphorus, and phosphatase were normal. Roentgenograms made when the patient was seventeen weeks of age showed massive cortical thickenings of the ulnas and radiuses, the sternal ends of the ribs and the mandible. Similar but less pronounced changes were demonstrated in the humeri, femurs and tibias. During the latter part of his six weeks' residence in that hospital the temperature ranged irregularly between 98 and 101°F. and the swellings of the forearms decreased slightly. He ate and slept normally and was comfortable when not disturbed by handling.

At five and one-half months of age the patient was transferred directly to the Babies Hospital. On admission he was found to be well nourished and appeared to be comfortable. The jaw and both forearms were, however, still visibly swollen (Fig. 5 and 6). The mandibular swelling was smooth and stony hard; it was most prominent at the angle of the mandible on the right side. There was no fullness in the parotid region. The regional lymph nodes in the submaxillary region and the neck were not enlarged and the mucous membranes of the conjunctivae and mouth were normal. The diffusely swollen right forearm was of a firm consistency and was non-tender. There was some limitation of motion of the left forearm but there was no tenderness or pain and the movements in the remainder of the body were normal. The right wrist was 13 cm. in circumference and the left wrist 11.5 cm. In the laboratory examinations the blood hemoglobin, the blood cells, urine, serum calcium and phosphorus, and sedimentation rate of erythrocytes were all found to be normal and Kline's test on the blood resulted in a non-syphilitic re-

Fig. 10. Case II. Dorsoventral projection of the right hemithorax which shows pleural thickening and costal cortical hyperostoses at five months of age.

action. The serum contained 22.6 Bodansky units of phosphatase.

Roentgenographic examination of the skeleton disclosed multiple hyperostoses with the distribution depicted in Figure 7. In contrast to Case I, the largest hyperostoses were in the forearms (Fig. 8), and the clavicles were not affected. The changes in the mandible (Fig. 9), on the other hand, were much greater than in Case I. Heavy pleural shadows similar to those seen in Case I were demonstrated on the right side (Fig. 10). Thoracentesis was not done and the nature of the pleural exudate was not determined.

No new manifestations developed during a hospital residence of eighteen days; the temperature was normal. The swellings of the forearms were subsiding at the time of discharge; at no time did signs of inflammation appear in these lesions. There was no recurrence of signs or symptoms later. The roentgenographic changes in the skeleton gradually diminished in size and density but were still visible in the radiuses and ulnas at ten months of age. The clinical and roentgenographic findings were normal in a follow-up examination at five years and five months of age.

Case III (B.H. No. 749,486), a male infant, was born on February 24, 1944, after a normal spontaneous labor and weighed 2.6 kilograms. The gestation was uneventful and the ante partum diet was adequate and balanced. During the first two months of life, the infant was healthy and gained normally. Orange juice and oleum percomorphum were given after the second month.

During the eighth week the "nose became stuffy"; fever was not recognized at this time and there were no constitutional symptoms. After several days the "nasal stuffiness" disappeared. During the tenth week, the mother observed that the infant's right cheek was swollen. One week after the appearance of this swelling the baby became hyperirritable, restless and refused food; the temperature was not taken but he did not appear to be feverish to the parents. The facial swelling and hyperirritability persisted for several days when roentgenograms of the jaws were made by the family dentist, who referred the patient to another hospital for investigation of a tumor of the mandible.

In the admission physical examination there, when the patient was twelve weeks of age, the abnormal findings included generalized pallor and swelling of the right side of the jaw. A hard mass attached to the right side of the mandible was palpable. Examination of the blood disclosed that the hemoglobin was reduced to 46 per cent and the erythrocytes to 2.3 million per cu. mm.; the leukocytes numbered 14,000 per cu. mm., there were 64 polymorphonuclears per hundred, 30 lymphocytes,

Fig. 11. Case III. Photograph which shows the swelling of the right cheek at four and one-half months of age, two months after its first appearance.

4 monocytes and 2 myeloblasts. Occasional leukocytes were found in the urine but no red blood cells. The serum calcium and phosphorus were normal: there were 24.2 units of alkaline phosphatase. Irregular elevations of temperature occurred in the hospital; recurrent fever of 100° F. developed and lasted irregularly for periods of forty-eight or seventy-two hours. Approximately one week after admission, a swelling of the left scapular region was seen for the first time. Roentgen examination revealed hypertrophy and sclerosis of the right side of the mandible, the left scapula, the left clavicle and cortical thickenings of several ribs and in

the tubular bones of the upper and lower extremities. The pleural layers on the lateral margin of the left lung were thickened.

At four months of age, six weeks after the first appearance of the facial swelling, the patient was admitted to the Babies Hospital. He was found to be well nourished and had a waxy

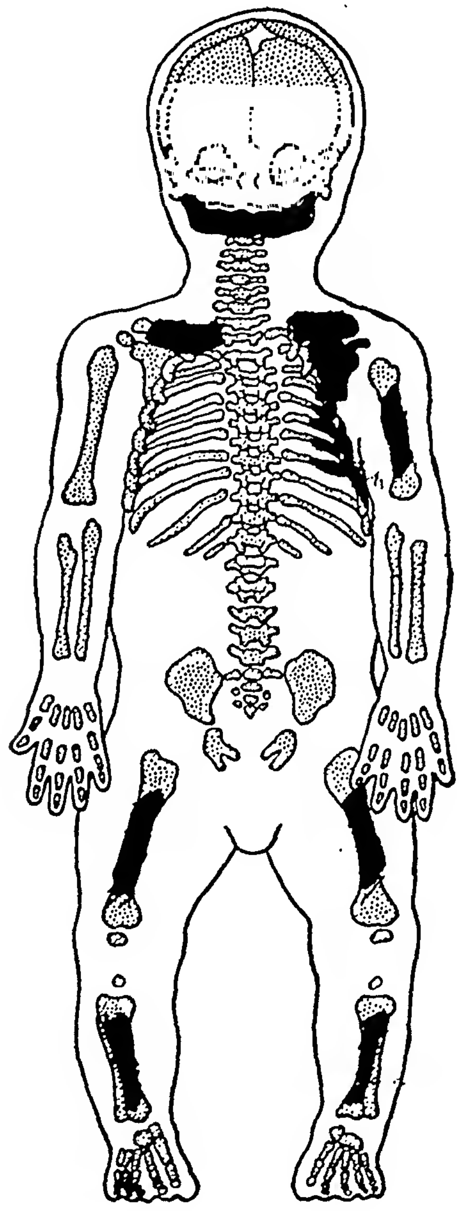


Fig. 12. Case iii. Spot map of the skeleton in which the shaded bones are the sites of cortical hyperostosis. The hyperostoses were greatest in the mandible, clavicles and left scapula.

papular eruption of the face which resembled seborrheic dermatitis. The right cheek and right side of the mandible were swollen (Fig. 11). The swellings were not tender at this time and the mandibular movements were not limited. The left clavicular and scapular regions were swollen but were not tender. The movements of the extremities were free and there was no swelling or tenderness in the arms or legs. The results in blood count, the urinary findings, bleeding time, clotting time and prothrombin time were all normal. The serum phosphatase was elevated to 45.8 Bodansky units; the serum calcium and phosphorus were normal. Culture of the blood yielded no bacterial growth. Kline's test on the blood gave a non-syphilitic reaction and the tuberculin test on the skin was negative. Agglutination tests of the blood for the typhoid dysentery group of bacteria resulted in no reaction and also for the organisms of brucellosis and cholera. In the roentgen examination, hyperostoses were demonstrated in the mandible, left scapula and clavicles (Fig. 12 and 13). The costal changes and the pleural thickening which were visible in roentgenograms made earlier at twelve weeks of age had disappeared completely.

The patient remained in the hospital for three weeks and was asymptomatic during this period. The mandibular and scapular swellings persisted unchanged. During the third hospital week a portion of the left scapula was removed; in the microscopic examination hyperplasia of normal bone was found. There was no evidence of inflammatory exudate or subperiosteal hemorrhage.

The swelling of the face and shoulder gradually diminished and had disappeaed completely at one year of age. In the roentgenograms made at this time the shadow of the left scapula was still slightly enlarged; but the patient was normal clinically.

Case iv (B.H. No. 612,819), a male infant, was born after a normal gestation and labor on January 25, 1940; he is reported to have weighed 4.8 kilograms. A formula made from evaporated milk was started at birth; cod liver oil with oleum percomorphum, one teaspoonful daily, and ascorbic acid, 25 mg. daily, were fed soon after birth but the exact time of beginning them was not ascertainable.

At birth a soft swelling was seen in the anterior portion of the neck which was thought to be a lipoma by the family physician. This cervical swelling is said to have gradually diminished in size during the first few days of life.

At about two weeks of age, swelling of the right scapular region and limitation of motion of the right arm at the shoulder were noted. The scapular mass was firm and tender but

Fig. 13. Case iii. Roentgenograms of the thorax at twelve weeks of age, *A*; and sixteen weeks, *B*. In *A* the soft parts in the left scapular region are thickened and the left scapula is enlarged and sclerotic but the clavicles appear to be normal. This roentgenogram was made when the scapular swelling was first recognized clinically. In *B*, the swelling and sclerosis of the left scapula has increased; in contrast to *A*, both clavicles are thickened and sclerotic. In a later roentgenogram, not shown, made at one year of age, the clavicular changes had disappeared completely but the sclerosis of the left scapula was still evident.

showed no signs of inflammation. The right arm was never completely paralyzed and there was considerable fluctuation in the movement of this extremity from day to day. A roentgen examination at ten weeks of age showed the right scapula to be enlarged and sclerotic but there were no abnormalities in the clavicles or ribs. Swelling and sclerosis of the left side of the mandible were visible in this roentgenogram and the right side of the diaphragm was elevated. During the tenth week the right shoulder was put in a cast which held the right arm in abduction. After about one month, the cast was removed and the motion of the right arm was said to have been greatly improved.

Three weeks after birth the left cheek and the left side of the jaw became swollen, tender and hard; and the patient had much difficulty in sucking food from the bottle. The swellings were not hyperemic and there was no increase in local heat. Fever, if present, was not detected by the mother. After about one week the left-sided facial swelling began to subside. During the sixth week of life the right cheek and the right side of the jaw became tender and swollen; this swelling began to subside after one week without any evidence of suppuration in the same fashion as the precedent left-sided facial swelling had decreased. Facial swellings of similar nature recurred twice on the left side and once on the right side during the first five months. There apparently were no associated constitutional symptoms; fever was not recognized at any time and there were no manifest disturbances of the alimentary, respiratory, genitourinary or nervous systems.

At five months of age, the patient was admitted to the Babies Hospital, four days following the appearance of the last of the recurrent swellings of the face. This swelling, on the right side, had already begun to subside at the time of admission. Both cheeks and the right side of the jaw were enlarged but not tender. The tissues in the right side of the neck were also thickened. Over the right scapula the tissues were swollen and indurated. The movements of the right arm were normal and its muscular power approximated that in the left arm. No information of positive diagnostic value was obtained from the laboratory examinations. The cellular elements in the blood were normal in number and structure. There were no abnormal urinary findings; there was no evidence of hematuria. The quantities of nonprotein-nitrogen, calcium, phosphorus and phosphatase in the blood were normal. Kline's blood test gave a non-syphilitic reaction and the Mantoux test caused no significant changes in the skin.

Roentgen examination disclosed massive hyperostoses in the mandible, right clavicle, right scapula and there were delicate lamellated thickenings of the right humerus and both femurs (Fig. 14). The left side of the mandible showed marked swelling and heavy sclerosis (Fig. 15). The right scapula and right clavicle

were also swollen and sclerotic, although their counterparts on the left side were unaffected (Fig. 16). In the roentgenoscopic examination, the right side of the diaphragm was elevated and partially paralyzed; the amplitude of its excursion was reduced to approximately 1 cm.

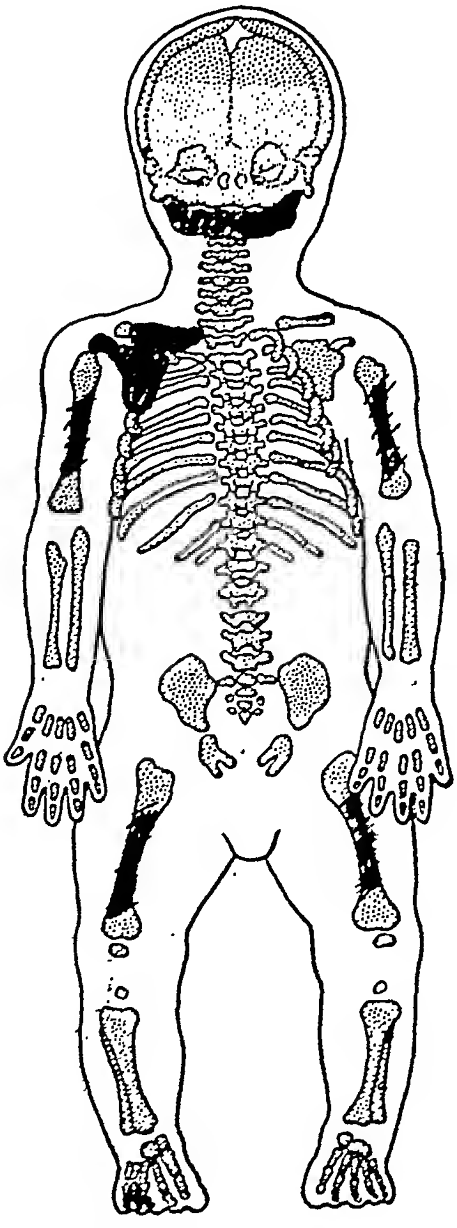


Fig. 14. Case iv. Spot map of the skeleton in which the heavily shaded bones are the sites of hyperostosis. The most marked changes are in the left side of the mandible, the right clavicle and right scapula.

In the tissues removed from the right scapular region a satisfactory specimen of bone was not obtained but in the muscular bundles attached to the perichondrium of the scapula many vacuolated fasciculi were seen.

The patient was asymptomatic during a hospital residence of three weeks save for fever during a few days which was associated with an upper respiratory infection. No new swellings appeared.

In a follow-up examination at four years and nine months, it was found that there had been no recurrence of the swellings and that the patient had enjoyed normal health during the interval of four and one-half years since the hospital observations. In the physical examination, however, the face was found to be asymmetrical; the left side of the face was larger

Fig. 15. Case iv. Roentgenogram of the mandible at five months of age, lateral oblique projection. The left side of the bone is sclerotic and diffusely thickened.

than the right and the left side of the jaw was visibly enlarged (Fig. 17). In the roentgen examination the left side of the mandible was larger and more opaque than the right side and the left zygomatic bone was enlarged and sclerotic. The clavicles and scapulas were normal. The right side of the diaphragm was still elevated as in the earlier examinations.

COMMENT

Maternal and Birth Histories. In all cases the mothers apparently enjoyed normal health and ate normal foods in normal quantities. None of the patients was born prematurely. In 3 cases the labors were

Fig. 16. Case iv. Frontal roentgenogram of the thorax at ten weeks of age, *A*, and five months, *B*. In *A*, the right scapula is already affected but the right clavicle is not abnormal. In *B*, the changes in the right scapula have increased and the right clavicle is now markedly thickened.

spontaneous and normal; in Case ii the patient was delivered after uncomplicated cesarean section. There is no evidence that prenatal deficiency of vitamins or obstetrical trauma was the cause of the infantile disturbances.

Onset. Much of the information concerning the onset is uncertain because most of the observations were made by the parents. It is certain, however, that the first manifestations became active during the first three months of life (Case i, seventh week;

Fig. 17. Case iv. Photographs at four years and nine months of age; *A*, frontal view; *B*, left lateral view. The face is asymmetrical owing to swelling of the left side of the face and the left submaxillary region. The facial swelling first appeared during the third week of life.

Case II, eighth week; Case III, tenth week; Case IV, second week). In every case the primary complaint was the appearance of tender swellings—in the thigh in Case I, in the face in Cases II and III, and in the scapular region in Case IV. Fever developed at the onset in Cases I and II; it was not recognized at the onset in Cases III and IV but may have been overlooked because temperatures were not measured. In the first phase of the disease, the swellings were tender but they did not show increased heat and they did not appear to be hyperemic. In Case IV, dysphagia appeared simultaneously with the facial swellings and limitation of movement at the right shoulder developed concurrently with the appearance of the swelling in the right scapular region. Prodromal symptoms were meager; fever and hyperirritability in Case I and stuffiness of the nose in Case III. Nasal obstruction in this case is the only manifestation suggesting that respiratory infection was present at the time of onset. Laboratory examinations were not made at the time of onset. During the second week of the disease in Case III, a blood count disclosed a moderately severe anemia.

Clinical Manifestations. In contrast to the multiple massive soft tissue swellings and the extensive scattered hyperostoses, there was a striking paucity of constitutional and systemic manifestations in all stages of the disease. Fever occurred in 3 cases. In Case I a low grade irregular fever persisted from the onset at the seventh week until the twelfth week and then recurred when bilateral sterile pleurisy developed during the fourteenth week. In Case II the fever was more severe—it began at the onset during the eighth week of life, reached levels of 103° F. and persisted irregularly until the patient was five and one-half months of age. In this case the temperature levels were highest when the swellings first made their appearance and when they were increasing in size. In Case III irregular mild fever was recorded in another hospital two weeks after the onset of facial swellings although fever had not been recognized earlier at home. In Case IV, who had a most severe clinical course and heavy recurrent hyperostoses, fever was never recognized during any stage of the disease either at home or in the hospital.

Visible and palpable tender swellings developed in all patients and they are the principal clinical components of the disorder. We did not have the opportunity of observing the swellings at onset or in the early phases when they were enlarging. One would opine from the parents' description that the swellings developed exceedingly rapidly—"came up over night"—in contrast to their slow subsidence. At no time was there any clinical evidence of hemorrhage or suppuration in these tumors. All were of a firm consistency early and became harder later. In the face, the soft tissues of the cheek anterior to the parotids were swollen as well as the lower jaw. No changes were detected in the adjacent mucosa of the mouth, and the overlying skin did not appear to be affected.

Swellings developed in the left leg in Case I; this is the only case in which facial swellings were neither visible nor palpable—notwithstanding, mandibular thickening was demonstrated roentgenographically. Pronounced swellings made their appearance in the face and both forearms in Case II; the former preceded the latter by nine weeks. These facial swellings fluctuated rapidly in size and disappeared and recurred several times. In Case III facial swelling developed during the tenth week and one week later the left scapular region became swollen. In Case IV in contrast, the right scapular region became swollen at two weeks and at three weeks a swelling appeared in the left side of the jaw. In this case, weakness of the right arm developed simultaneously with the appearance of the scapular swelling and considerable dysphagia was associated with the onset of the facial swellings. It should be emphasized that there were no clinical signs of swelling in many other sites—in the clavicles, ribs and long bones where hyperostoses were

demonstrated roentgenographically. It is therefore evident that only the largest and tender lesions have been detected clinically and the majority of hyperostoses were overlooked until roentgen examinations were made; and it seems probable that many mild cases without conspicuous clinical signs have not been subjected to roentgen studies and have not been recognized.

Laboratory Findings. All of these patients remained at home during the earliest stage of the disease and no laboratory observations were made until considerably later. The details of the later laboratory findings are given in the case reports; little information of positive diagnostic value was obtained from them. Serological tests for syphilis gave non-syphilitic reactions in all cases. The quantitative studies of the concentrations of ascorbic acid in the blood and the urine in Case I did not support the diagnosis of scurvy. Agglutination tests on the blood and cultures of the blood disclosed no findings suggestive of bacterial infection. Smears and cultures of pleural exudate in Case I yielded no bacteria. Examination of the blood revealed no evidence of hemorrhagic disease and there was no hematuria.

Biopsies of affected bones in 3 cases showed only hyperplasia of the lamellar cortical bone; there was no evidence of inflammation or of subperiosteal hemorrhage. In both clinical and roentgen examinations, pronounced changes were demonstrated in the soft parts adjacent to the hyperostoses. We did not have the opportunity to make early biopsies of the soft tissue and bone when they might have been more informative.

Roentgen Findings. In the roentgen observations, scattered bones and their overlying soft parts were found to be thickened in all 4 cases, the pleurae thickened in 3 and the diaphragm paralyzed and elevated in 1 case.

In the skeleton, the basic roentgen change is an external thickening of the corticalis; this thickening was lamellated in many instances. The external margins of the cortical swellings were irregular in numerous bones (see Fig. 2, 3*A*, 8 and 13*B*). It is noteworthy that in the lower extremities the cortical thickenings do not extend the entire length of the corticalis but leave the terminal segments of the shafts unaffected (see Fig. 2). In contrast, the subperiosteal hemorrhage in scurvy and its subsequent cortical thickening begin directly on the end of the corticalis at the cartilage-shaft junction. In the unaffected as well as the affected bones the spongiosa, the metaphyses, the epiphyseal plates and the ossification centers in the epiphyses all were normal roentgenographically. In not a single bone were there metaphyseal spurs or fractures of the epiphyseal plates or the adjoining lattice. The changes in the bones, therefore, not only do not support the diagnosis of scurvy but the absence of all the basic scorbutic changes is convincing evidence that the skeletal lesions are not due to deficiency of vitamin C. It is clear that the soft tissue changes are confined to the neighboring muscular bundles and do not extend into the overlying subcutaneous fat. The soft tissue swellings evidently preceded the formation of the hyperostoses (see Fig. 13, *A* and *B*, and 16, *A* and *B*).

The incidence and the distribution of the skeletal and pleural lesions in 4 cases are shown in Table I. The mandible was ex-

Table I

Case	Mandible	Clavicles	Scapulas	Ribs	Extremities	Pleura
I	++	++++(2)	0	++++	++++	++++
II	++++	0	0	++++	++++	++++
III	++++	++++(2)	++++	++++	++	++
IV	++++	++++(2)	++++	0	++	0

tensively swollen in all 4 cases; in Case I the mandibular swelling was not noted clinically and it was less extensive roentgenographically than in the other 3 cases. The absence of clinical swellings and tenderness in many regions where hyperostoses were demonstrated roentgenographically has already been commented on. Actually most of the hyperostoses would have been missed had the roentgen examination been limited to the sites of the clinical swellings. It is probably equally true that slight soft tissue swellings are readily overlooked both clinically and roentgenographically in this disease. We are not certain of the state of the facial bones other than the mandible because they were not adequately visualized roentgenographically.

The clavicles exhibited roughened cortical thickenings in 3 cases which appeared to be similar to those in the tubular bones of the extremities. Tenderness and pain were not associated with the clavicular lesions.

The massive involvement of the scapulas in Cases III and IV was a conspicuous and surprising finding. Only one scapula was affected in each of these patients and in each of them the hyperostoses in the long bones were not pronounced although their mandibular lesions were marked. The scapular changes appear to be due to cortical hyperplasia as in the other bones.

The ribs showed multiple involvement in Cases I, II and III. There was no clinical evidence of costal disease in any of these patients. It is possible that costal changes also developed in Case IV but were not demonstrated because roentgenograms were taken at too long intervals. In Case III the costal changes were not visible in the twelfth week, were clearly visible in the thirteenth week, but had disappeared completely in the seventeenth week. The costal thickenings were multiple in Cases I, II and III; and were bilateral in Cases I and II.

The greatest changes in the extremities were found in the legs in Case I and the forearms in Case II. The external margins of the largest hyperostoses were irregular in contrast to the smooth external margins of most of the smaller hyperostoses. As previously stated, the hyperostoses in the bones in the extremities were minimal in both cases in which scapular hyperostoses were identified.

Pleural exudate of sufficient magnitude to be visualized roentgenographically developed in Cases I, II and III. It is noteworthy that pleural exudate was demonstrated in the 3 cases in which costal thickenings developed but was not seen in Case IV in which costal hyperostoses also were not visualized. The close relationship of the pleural exudation and costal hyperostosis is also shown by the fact that the pleural exudate was bilateral in the 2 cases in which the costal lesions were bilateral (Case I and II); unilateral, left-sided pleurisy developed in Case III and the costal disease was also unilateral and left sided. The pleurisy did not develop concurrently with the other bone lesions, however. In Case I pleural exudate appeared seven weeks after the initial symptom of pain and swelling of the left thigh.

The right side of the diaphragm was found to be elevated and partially paralyzed in Case IV in the first roentgenoscopic examination. It is possible that this lesion developed at birth and was due to obstetrical injury to the phrenic nerve[9] or was of prenatal origin and was caused by pinching of the phrenic nerve between the fetal spine and shoulder girdle.[1] The associated weakness of the right arm may have been due to birth injury to the brachial plexus. The parents, however, were certain that the movements of the right arm were normal until two weeks after birth when the right-sided scapular swelling appeared. Perhaps the paralysis of the diaphragm and the weakness of the arm resulted from pressure on the phrenic nerve and brachial plexuses, respectively, by the large soft tissue swelling which developed in the right shoulder and right side of the neck during the second week of life. The weakness of the arm gradually improved and disappeared; the diaphragmatic weakness per-

sisted and was still present when the patient was four years and nine months of age.

The clinical and roentgen pictures of this disorder are probably more protean than the findings in the first 4 patients indicate.[7] Undoubtedly study of more patients will provide many modifications of our current concepts and add some new features. Already we have data on 3 additional patients who showed many findings similar to the 4 described above and it is likely that all 7 were affected by the same disease. In 1 case the clinical and roentgen swellings were limited to the face and mandible; treatment with sulfathiazole was completely ineffective—the fever persisted and mandibular swellings developed and extended during the administration of sulfathiazole. In a second the onset occurred during the eighteenth month of life, and the mandible and face were unaffected although extensive hyperostoses were found in the clavicles, ribs and tubular bones of the extremities including the metatarsals. In a third patient studied by Dr. Bruce Chown of Winnipeg, Canada, serial roentgen examinations early in the disease demonstrated clearly that the soft tissue swellings preceded the hyperostoses; in this case the swellings recurred in the face after and during the administration of large quantities of ascorbic acid.

Course and Duration. The active manifestations subsided completely after several weeks and there were no serious complications. The only sequelae occurred in Case IV—persistent facial swelling and diaphragmatic paralysis at four years and nine months (see Fig. 17). The fever was irregular and inconstant. In different patients the magnitude of the fever varied markedly from high long-sustained febrile episodes in Case II to absence of fever in Case IV. Fever recurred synchronously with the appearance of pleurisy in Case I; the histories suggest that fever also recurred or increased at the same time the facial swellings recurred in Case II. The swellings appeared suddenly, enlarged rapidly and subsided gradually after many weeks; they were tender only during the early phase of swelling. The abrupt onset of the swellings is not unlike the sudden appearance of tumors caused by angioneurotic edema; there was, however, no pruritus and no vesiculation or other associated allergic phenomena.

The course of the pleurisy could be followed only in Case I. Fever recurred at the time the pleural exudate was identified roentgenographically and persisted for thirteen days. There were no diagnostic physical signs or symptoms nor was there associated exacerbation of the swelling of the thigh.

The cortical thickenings gradually diminished and disappeared completely after several months; the skeletons were normal roentgenographically in the late follow-up examinations except in the mandible of Case IV. The marginal irregularities which were present early disappeared as the hyperostoses became smaller. There were surprisingly few "transverse lines" in the later roentgenograms.

Differential Diagnosis. During the study of these patients several diagnoses were entertained but none seems tenable after evaluation of all the findings. Scurvy can be ruled out on practically all counts—onset during first weeks of life, adequate intake of vitamin C by both mothers and infants, facial swellings which recurred during and after adequate administration of vitamin C, lack of hematuria, and in the roentgenograms absence of metaphyseal and epiphyseal changes and the presence of mandibular hyperostoses.

The clinical manifestations were not characteristic of syphilis; the serologic reactions were non-syphilitic; mandibular involvement and absence of signs of osteochondritis in the presence of extensive diaphyseal changes are both inconsistent with skeletal syphilis of the early weeks of life. Trauma and injury prior to the onset were not observed in any case and the recurrences in the hospital were certainly not associated with trauma. Neoplasia need

not be considered in view of the results of the biopsies and the benign clinical course.

Infection cannot be excluded so satisfactorily. The long febrile course in Case II and the febrile episodes in Cases I and III suggest that infection was the causal agent. The development of pleural disease in 3 patients and especially the cellular reaction of 500 monocytes per cubic millimeter in pleural exudate of Case I, the only case in which there was an opportunity to examine the pleural liquid, strongly suggest infection. Bacterial infection was not proved in any case—none of the swellings was suppurative, biopsies disclosed no evidence of inflammatory reactions in the affected bones, blood cultures and agglutination tests were negative, and smear and culture of the pleural exudate yielded no bacteria. We were unable to investigate virus infection adequately.

Rivers[8] has demonstrated that experimental virus infection of the cornea may be followed by a reaction that is exclusively hyperplastic without cellular infiltration. A similar hyperplastic reaction in the osteogenetic layer of the periosteum could conceivably be responsible for the cortical hyperplasia found in these bones. So far as we know, hyperplastic osteitis has not been recognized in human virus infections. Councilman and his colleagues[4] found focal necroses in the bone marrow of the vertebral bodies in smallpox but they do not mention cortical involvement. Virus infections during early infancy may be more common than is generally appreciated by clinicians, as indicated by the reports of Von Glahn and Pappenheimer,[10] Farber and Wolbach,[5] Kinney,[6] and Buddingh and Dodd.[2]

The exceedingly rapid development of the facial swellings in our patients resembles the sudden appearance of angioneurotic tumors. Pruritus was not associated and there was no concomitant eosinophilia. Subperiosteal allergic edema is a possible cause of the cortical thickenings; allergenic edema may also have been responsible for the swellings in the neighboring soft parts.

The data in this group of cases indicate that the clinical and roentgen manifestations represent a new syndrome. The cause is at present undetermined. The possibilities of virus infection or allergic reaction as the causal mechanisms deserve consideration in the investigation of future patients whose findings suggest that they are affected.

REFERENCES

1. Blattner, R. J. Unilateral paralysis of diaphragm without involvement of brachial plexus. *J. Pediat.*, 1942, *20*, 223–229.
2. Buddingh, G. J., and Dodd, K. Stomatitis and diarrhea of infants caused by a hitherto unrecognized virus. *J. Pediat.*, 1944, *25*, 105.
3. Caffey, J. Syphilis of skeleton in early infancy; nonspecificity of many of the roentgenographic changes. Am. J. Roentgenol. & Rad. Therapy, 1939, *42*, 637–655 (see Case xix, p. 649).
4. Councilman, W. T., Magrath, G. B., and Brinckerhoff, W. R. Pathological anatomy and histology of variola. *J. Med. Research*, 1904, *11*, 12–135.
5. Farber, S., and Wolbach, S. B. Intranuclear and cytoplasmic inclusions ("protozoan-like bodies") in salivary glands and other organs of infants. *Am. J. Path.*, 1932, *8*, 123–136.
6. Kinney, T. D. Intranuclear inclusions in infancy. *Am. J. Path.*, 1942, *18*, 799–811.
7. Personal communication. We have compared data with Dr. F. S. Smyth who is studying a similar group of 4 patients at the University Hospital in San Francisco, California. His cases are to be reported in *Am. J. Dis. Child.* during 1945.
8. Rivers, T. M. Lane Medical Lectures: Viruses and Virus Diseases. Stanford University Press, 1939, p. 42.
9. Tyson, R. M., and Bowman, J. E. Paralysis of diaphragm in the new-born. *Am. J. Dis. Child.*, 1933, *46*, 30–39.
10. Von Glahn, W. C., and Pappenheimer, A. M. Intranuclear inclusions in visceral disease. *Am. J. Path.*, 1925, *1*, 445–466.

HYPERTROPHIC PYLORIC STENOSIS IN INFANTS

ROENTGENOLOGIC DIFFERENTIAL DIAGNOSIS*

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LITTLE has been written on the use of the roentgen ray in the diagnosis of hypertrophic pyloric stenosis in infants. This is probably due to the fact that in the past the roentgen department was not given the opportunity of making many gastrointestinal studies on infants in whom pyloric muscle hypertrophy was suspected clinically. Among the many reasons were:

1. A history of bile-free vomiting in an infant three to six weeks old with a palpable mass in the epigastrium to the right and above the umbilicus and visible abdominal waves corresponding to gastric peristaltic activity was considered sufficient clinical evidence to warrant a diagnosis of pyloric muscle hypertrophy with varying degrees of stenosis.

2. If symptoms persisted after a change of formula, and the administration of antispasmodics, surgery was indicated.

3. Many clinicians and surgeons not only believed that a roentgen examination was unnecessary but strongly objected to the use of barium for fear of aspiration and so forth.

4. The difficulty of removing barium by lavage leaves a residue which may interfere with operative procedures.

5. The request to withhold food for six hours or more during the roentgen examination interfered too greatly with the nutritive requirements of the infant.

In our experience it was usually the less severe cases, those in which the clinical findings were not clear cut, when there was no dehydration, no definite nutritional disturbances and the infant appeared healthy, that roentgen examination was resorted to, and then chiefly to estimate the rate of gastric motility. Occasionally, at the request of the pediatrician, a small amount of barium was added to the formula simply as a "tracer" medium to determine gastric emptying time. This usually confused the picture, as delayed motility was due to the presence of fat, and to a lesser degree protein and carbohydrate in the formula. Too short a time interval between the last feeding and the administrations of barium also resulted in delayed emptying time in the normal infant, yet, under these circumstances, a retarded gastric motility with prolonged emptying time was often accepted, in conjunction with symptoms and clinical findings, as sufficient evidence for operative intervention. A water-barium mixture should be given on an empty stomach, at least four hours after the last feeding.

There are numerous factors influencing the emptying time of the normal infant's stomach, and infants, healthy in every respect, often show small gastric residues at the end of ten, twelve, and even twenty-four hours. A common cause of delayed gastric motility is gaseous distention of the gastrointestinal tract. Infants are notoriously aerophagic, not only while feeding but also in the act of crying, yawning and stretching. Atmospheric air apparently enters the stomach with ease in deep inspiration when the esophagus is apparently put on a "stretch" and filled with atmospheric air. This is probably aided by the fact that the ratio of the height to the width of the chest in infants is much less than in normal children and adults. Whether relaxation or hypotonicity of the esophageal sphincter plays a part in the admittance of air into the stomach is indefinite. However, with the stomach and small intestine distended with gas and the infant allowed to remain in the supine posi-

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Fig. 1. Lateral recumbent view showing relationship of cardiac end of stomach to gas-distended antral end. In this position the emptying time may be prolonged two or three times that of normal.

tion, there is a definite tendency toward delayed gastric motility and prolonged emptying time, for so long as the patient is kept in the supine position, little of the gas can escape from the stomach through the esophagus.

Apparently only a negligibly small amount of swallowed air is absorbed from the intestine by the blood stream. That the gas in the stomach and small intestine is largely swallowed air can be demonstrated in an abdomen previously free of gas by observing its gradual accumulation during feeding or the act of crying, first in the stomach, then the upper small intestine, and gradually the lower portion of the small intestine and finally the cecocolon.

Under these conditions, we have encountered as high as 40 to 50 per cent gastric retention at the end of ten hours and 20 to 25 per cent at the end of twenty hours.

Repeating the examination several days later, after the elimination of most of the gas from the stomach and practically all of the gas from the small intestine (by placing the infant for several hours in the semirecumbent prone position with slight elevation of the right shoulder), we encountered normal gastric emptying time of two to two and a half hours.

The abdomen should be almost free of intestinal gas before water-barium is administered on an empty stomach. Under these circumstances, extraneous influences of gas are eliminated and a more accurate evaluation of gastric motility is thereby determined.

Apparently gaseous distention of the small intestine reflexly *inhibits* gastric peristaltic activity and delays motility. In the prone position most of the gas in the stomach and possibly a small amount in the upper small intestine is regurgitated through the esophagus while that remaining in the small intestine is propelled into the colon. If by this method, the small intestine cannot be rid of gas, an investigation of the tension of the anal sphincter should be made, for in sphincterismus ani, the colon remains distended and prohibits the caudad movement of gas in the small intestine.

In two instances of vomiting with delayed gastric motility, the vomiting ceased and there was a return to normal gastric motility following correction of an anal sphincter spasm.

This gaseous distention of the small intestine does not as a rule take place if, after feeding, the infant is immediately placed in the semirecumbent prone position where the gas is readily regurgitated through the esophageal opening which now occupies a position atop the gastric gas bubble.

Fig. 2. Anteroposterior view (supine position) showing rounded appearance of barium in cardiac end and accumulation of gas in pyloric end. Neither the cap nor pyloric canal is visualized in this position.

In the supine position, however (Fig. 1), the swallowed air in the stomach rises above the esophageal opening and occupies the pars media and the pars pylorica at a level above the hiatus; thus it cannot be regurgitated through the esophagus, and the ingestion of any liquids merely forms a "pool" (Fig. 2) in the dependent cardiac portion of the stomach which literally "seals off" the cardiac orifice. Further ingestion of formula merely increases the gas pressure and gradually forces the swallowed air through the pyloric canal into the upper small intestine. At times, an additional accumulation of air in the high arched pyloric antrum seems to act as a "gas trap" and prohibits the egress of barium through the pyloric ring. These are the stomachs in which the barium appears as a round dense shadow in the upper left quadrant in the supine position, surrounded by a large tubular gas shadow tapering off to the right of the spine at a slightly lower level. When the stomach is greatly distended with gas, no peristaltic activity is encountered and there may be little or no motility over a period as long as twenty hours (Fig. 3).

Changing the infant from the supine to the prone position reverses the relationship of the gas and fluid contents of the stomach. The gas now accumulates in the high cardiac end of the stomach where it can readily be expelled through the esophageal opening and the barium comes to occupy the pars pylorica where, in the normal infant, normal gastric motility follows.

PROCEDURE

1. Two erect 8 by 10 inch roentgenograms are taken at 6 feet (posteroanterior and lateral at 1/20 second) within one-half hour of last feeding. These roentgenograms include the chest and abdomen. By using chest technique and including the lung fields, one can eliminate the presence of atelectasis or pneumonic consolidation, particularly the chronic type of pneumonias, as a cause of anorexia and vomiting, for the latter may run a normal temperature and not be suspected clinically. The retropharyngeal space and esophagus when filled with air are also visualized in the lateral view. Occasionally, bulging of the posterior pharynx due to cellulitis will interfere with the swallowing function and account for regurgitation.

Fig. 3. Lateral view showing small umbilical hernia.

2. The amount of gas and fluid in the stomach and the distribution of gas in the small intestine are noted. Normally gas in the small intestine is evenly distributed throughout the jejunum and ileum. If the distribution of gas is largely limited to one side or one quadrant of the abdomen, it presupposes the possibility of some congenital malformation (Fig. 4) such as anomalous mesenteric attachments, nonrotation, various types of intra-abdominal hernias, congenital bands, and so forth.

A variable portion of proximal small intestine outlined by gas, sharply delimited in the upper abdomen but an absence of small intestinal gas in lower abdomen and pelvis strongly suggests the possibility of congenital bands. With congenital duodenohepatic bands, only the stomach and first and second portions of duodenum may be distended with gas, while in "Lane's kink" type the entire intestine, exclusive of the right lower quadrant may be distended, and in the various types of congenital intra-abdominal hernias, gas-filled loops are "bunched together" and segregated more or less in one part of the abdomen. In the absence of these types of congenital anoma-

lies, there is a segmented distribution of gas in the small intestine; thus it is advantageous to have gas in the stomach and small intestine for the initial survey roentgenogram in the erect position. Its total absence is strongly suggestive of atresia of the esophagus, although this is found in very early infancy and not in the period when pyloric hyperplasia is suspected.

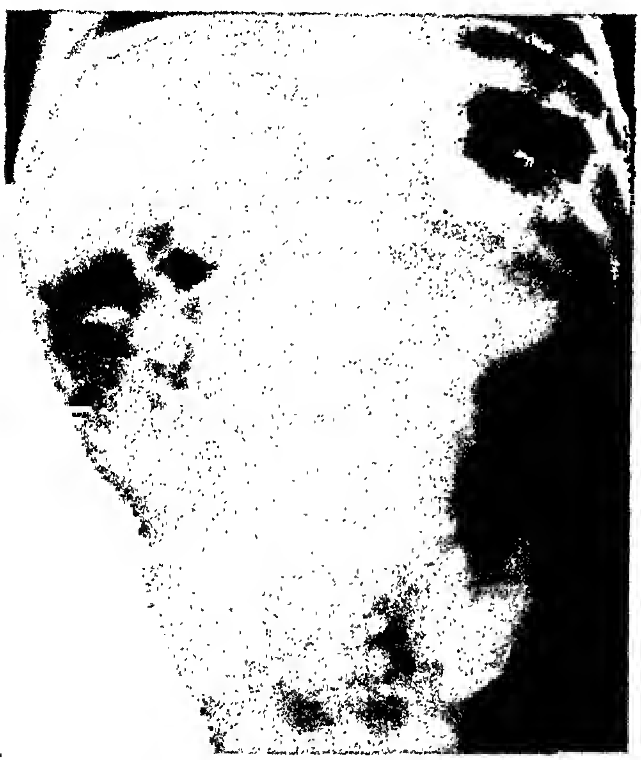

Fig. 4. B. A., aged one month. Note collection of small intestinal gas in upper right quadrant. Postoperative diagnosis: anomalous mesenteric attachment of small intestine with many loops bunched together and volvulus. Patient died two weeks following operation.

3. The infant is now placed in the semirecumbent prone position for approximately three hours or longer in an attempt to get rid of all the gas in the small intestine and most of the stomach gas. This is important, for a gas-distended small intestine will have an effect similar to an "adynamic ileus" and greatly retard gastric motility; it may even be the cause of vomiting. So, along with the variability of the normal gastric emptying time and the cyclic propulsion of the barium through the pyloric ring, we have the additional influence of a gas-distended small intestine. The standard water-barium mixture is administered through an ordinary nipple and, roentgenoscopically, the esophagus and swallowing function are observed and the size, shape, position, tonus and quality of gastric peristalsis noted. The amount of the opaque medium administered corresponds to that of the formula for the age of the infant (2 ounces is usually sufficient). If there is any hindrance to the passage of barium through the pyloric canal, one usually encounters vigorous peristaltic action with deep waves passing along both curvatures. In the early stages it presents the picture of a "fighting stomach." These contraction waves are seen mostly in the pyloric antrum and middle third. Visualization of the duodenal cap depends upon the degree of patency of the pyloric canal: if the latter is markedly narrowed, or, in the presence of pylorospasm it is impossible to fill the cap and the latter is represented only by small specks of barium. In those cases with symptoms of relatively long standing, i.e., two weeks or longer of intermittent projectile vomiting, one will not encounter a tonic stomach of normal size with vigorous peristaltic waves, but a dilated, atonic type of stomach with little or no visible peristaltic action, and, when peristalsis is observed it is feeble and superficial in character. When this stage of myasthenia gastrica is reached, there is almost complete pyloric obstruction and in this stage of exhaustion the patient no longer vomits.

4. Antispasmodics are administered to the infant throughout the examination in an attempt to eliminate the factor of spasm. In spasm per se, there is a marked variability in length and width of the pyloric canal; it becomes markedly elongated in antral spasm. However, if a sufficient number of exposures is made at the right time, i.e., during and following a contraction wave, one can usually demonstrate a pyloric canal of variable length. At least one roentgenogram will show a canal of several millimeters in length (Fig. 5).

5. Roentgenograms are taken at one half hour intervals in order to record the peri-

odic emptying of the stomach, for motility in infants is normally much more variable than in adults. Hence, if there is little or no motility during the first two or three "half-hour" periods, the fourth "half-hour" interval may show normal motility with good visualization of the duodenal cap. In the event of good visualization of the duodenal cap, the gastric motor function is considered to be within normal limits even though the emptying time may be prolonged to four to six hours or more. Pylorospasm may show very little motility

Fig. 5. Normal cap and pyloric canal showing antral contraction. The pars media "tapers" gradually and merges imperceptibly with the pyloric canal.

during the first hour, while the second hour may show emptying of the major portion of barium from the stomach. Three hours is considered long enough time in which to get a record of at least one cycle of activity in order to estimate the rate of motility and the anatomical status of the pyloric canal. In the intervals between examinations, the infant is kept in a semirecumbent prone position.

As soon as gastric peristalsis is encountered, serial roentgenograms may demonstrate the pyloric canal and its variability, if any, in length.

In pyloric muscle hypertrophy, there is no variability in the length of that prepyloric segment and no cycles of gastric motility. There may be an apparent variation in the length and diameter of the pyloric canal as a whole, but there is one prepyloric

Fig. 6. B. A., male, aged five weeks. Projectile vomiting one week. Hypertrophic pyloric stenosis. Note narrow elongated and relatively straight pyloric canal measuring 2.5 cm. in length, not influenced by antispasmodics. The barium stops abruptly along proximal border of tumefaction which is convex towards lumen of stomach with the formation of "shoulders." Operation—pyloromyotomy (Fredet-Rammstedt type) with complete relief of symptoms.

segment that is constant and unchanging in length and caliber of lumen. This segment is longer and the lumen narrower than what we believe to be the normal length and width of the pyloric canal in infants. Under these circumstances we have re-

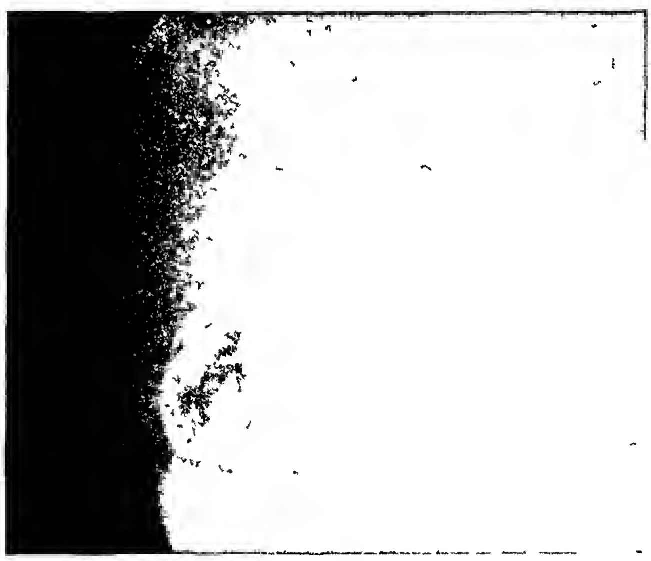

Fig. 7. E. F., female, aged six weeks. Projectile vomiting one week. Waves were observed across abdomen but no masses palpable. The pyloric canal is curved and markedly elongated—3 cm. Duodenal curve normal. Note the "shoulder appearance" on either side of pyloric canal. Operation—pyloromyotomy (Fredet-Rammstedt type). Symptoms relieved.

examined a limited number of patients with and without antispasmodics and found no alteration in that portion of the prepyloric canal elongated and narrowed by local pyloric muscle hypertrophy or change in the ultimate emptying time of the stomach. On the other hand, gastric motility in pure

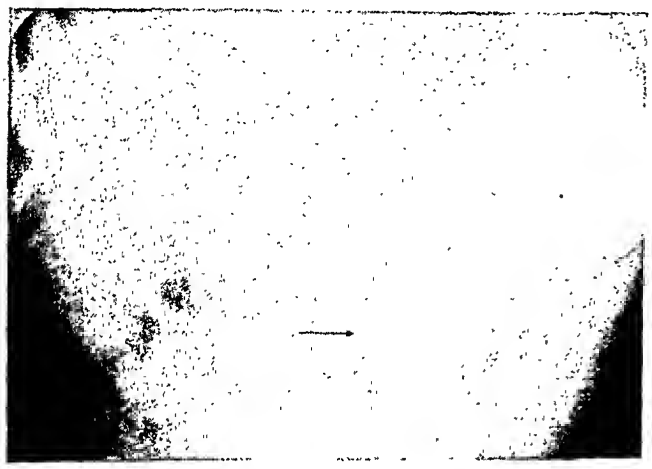

Fig. 8. M. S., female, aged nine weeks. Vomiting after feeding—past week. Note linear pressure defect running across pyloric antrum. Operation—congenital gastrohepatic band.

pylorospasm is influenced by time and antispasmodics. The latter largely eliminate the initial retarded motility encountered in the first and second half-hour intervals and the ultimate emptying time may be brought to within almost normal limits.

In pyloric muscle hypertrophy (Fig. 6 and 7), the amount ejected from the pyloric canal depends upon the degree of narrowing, but there is a rather regular and constant ejection of barium into the duodenum from the time barium is introduced into the stomach until it is nearly empty. The last 25 per cent may require more time for evacuation than the initial 75 per cent—this may be due to a gradual subsidence of the vigorous, intermittent peristaltic waves observed at the beginning of the examination. One must remember, however, that in a normal stomach the rate of motility decreases as the stomach empties, and it is not uncommon to find traces of barium in the normal infant's stomach ten to twenty hours following the barium meal.

When congenital bands run across the pyloric end of the stomach and exert sufficient pressure to interfere with gastric motility, we likewise encounter hyperperistalsis. Here, however, when the stomach antrum is in a state of diastole and filled with barium, a sharp line of demarcation running from the lesser to the greater curvature can often be demonstrated in the form of an extrinsic linear pressure defect seen in the posteroanterior recumbent, or lateral erect roentgenogram (Fig. 8). This defect may be produced by a gastrohepatic or gastrocolic band or persistent mesogastrium. The pyloric canal may show a marked variability in its length and caliber. Here, as in localized pyloric muscle hypertrophy, the duodenal cap may never be completely filled, but there is complete absence of a persistent narrowed and elongated prepyloric segment.

A congenital peritoneal fold impinging on the lumen of the small intestine will show stasis and possibly some dilatation proximal to the points of obstruction; when it involves the duodenal loop proximal to the ampulla, the vomitus is not bile stained. The size of the cap and degree of dilatation of the duodenum will depend, to a certain

Fig. 9. A. C., female, aged one month. Note the elongated pyloric canal, stasis and dilatation of the duodenum with reversal of its curve and abrupt ending of barium near duodenojenunal junction. Operation—(1) congenital hypertrophic pyloric stenosis and (2) anomalous mesenteric attachment with volvulus of small intestine just proximal to ligament of Treitz. (Second and third portion of dilated duodenum outlined as seen on original roentgenogram.)

extent, upon the duration and degree of obstruction. There may be stasis, but very little dilatation of the intestine in mild stenosis and recurrent volvulus due to abnormal peritoneal folds or volvulus associated with non-rotation of the colon.

Intrinsic obstruction is more common than extrinsic in the newborn. In atresias, the newborn begins vomiting soon after birth. Vomiting is persistent and bile stained. The stomach and entire small intestine proximal to the point of obstruction are distended even at birth by accumulation of digestive juices and swallowed amniotic fluid. An erect roentgenogram soon after vomiting may show a large gas-distended stomach and small intestine proximal to the point of obstruction; the rest of the small intestine is non-air containing. This finding, plus the clinical history, is sufficient evidence to warrant a diagnosis of small intestinal obstruction and the administration of barium may yield no further information, although it may be possible to completely fill the duodenal cap—a finding not encountered in pyloric stenosis. Volvulus may produce a somewhat similar picture, but here the obstruction may be intermittent and small amounts of gas or barium may outline the small intestine distal to the point of obstruction and examination during an asymptomatic period may reveal nothing abnormal. These patients should be examined immediately after an episode of vomiting. Gastric hyperperistalsis was never encountered in either complete or incomplete obstruction distal to the pyloric ring. In hypertrophic pyloric stenosis, vomiting usually occurs for the first time during the third to fifth week of life with a gradual increase in the severity of symptoms and prior to this time there may have been no feeding problem. During the first few days of vomiting, the stomach is orthotonic and normal in size; later it enlarges and becomes atonic. We have not encountered complete obstruction in any case of pyloric muscle hypertrophy and once the barium enters the small intestine it proceeds normally to the cecum, showing a variegated and segmented pattern of the small intestine. Well filled continuous loops are not encountered in retarded gastric motility.

In order to appreciate the roentgen appearance of pyloric muscle hypertrophy, a brief description of the gross anatomic findings may be helpful.

The pylorus presents a fusiform, olive-sized hyperplasia, presumably of congenital origin, involving the circular muscle fibers of the pyloric canal. It terminates abruptly at the pyloric ring; the caliber of the lumen is decreased, its external surface smooth and almost as firm as cartilage. Origin on an endocrine basis is a possibility, as it occurs in males at a ratio of 3 to 1 and in some series as high as 10 to 1. It has been reported in male twins. That reflex pylorospasm should produce a tumor mass of this size and character within a period of three weeks is rather unlikely. Spasmophilia as a factor must be considered.

On serial roentgenograms, the elongated and narrow caliber of the pyloric canal can usually be demonstrated. It ranges in length from 0.5 cm. to 3 cm. In severe cases, the canal may be represented by a mere thread of barium which is constant and uniform, while in others there is very little diminution in caliber, although there may be marked elongation. The caliber is persistent and unchanging in configuration and not influenced by antispasmodic drugs. The canal may appear to change in length but this is due merely to superimposed antral contractions. The tumor stops abruptly at the base of the duodenal cap. At the antral end it may merge gradually with the stomach wall, but more often it is seen to project convexly into the lumen of the stomach, forming "shoulders" about the proximal aperture of the canal. If only a segment of the canal is visualized, it appears as a small "beak-like" process of barium, its base resting on the "shoulders" in the midline and its point directed toward the cap. We were unable to demonstrate any depressions, crevices, or suggestions of mucosal folds in the canal or deep trans-

verse sulci or gastric mucosa at the proximal portion of the tumefaction. Neither was there any evidence of a concavity at the base of the duodenal bulb as a result of a partial invagination of the hypertrophied muscle, described by Kirklin[1] as occurring in pyloric muscle hypertrophy of adults.

The normal pyloric canal as seen on serial roentgenograms, varies in length and caliber according to the degree of pyloric and antral contraction. That short segment of pyloric canal adjacent to the base of the bulb, which is constant in length and caliber in diastole, represents the pyloric ring. This measures, on an average, 2 mm. in diameter and a variable 2 to 4 mm. in length on roentgenograms taken at a 36 inch distance. The greater and lesser curvature merge gradually toward the base of the duodenal cap. In the absence of any gastric or small intestinal gas, the normal infant's stomach will evacuate the major portion of the barium meal, i.e., 75 to 85 per cent, in two and a half hours when in the prone position. This was considered as a normal rate of gastric motility during one of its periodic cycles of evacuation. Realizing the difficulty in ascertaining a true estimate of the amount evacuated during any one time period, a fair estimate of the rate of motility was based on the ease with which the cap filled and to a lesser degree the pattern of the upper small intestine. With rapid gastric motility, there is either a continuity of or a closer approximation of the segments of barium in the small intestine.

In those cases in which congenital lesions occur distal to the pyloric ring, involving the small intestine, such as congenital atresias or stenosis, duodenohepatic bands, Lane's kink, anomalous mesenteric attachments of the small intestine with recurrent volvulus, intra-abdominal hernias of various kinds, etc., the stomach appears atonic, slightly dilated with shallow, superficial gastric peristaltic waves occurring at lengthy intervals; gastric hyperperistalsis is seldom encountered. The pyloric canal is within normal limits and the duodenal cap can usually be completely filled. The barium is not ejected into the duodenum with any degree of regularity as in hypertrophic pyloric stenosis, but is ejected spasmodically at extremely long intervals. The cap fills readily and completely on manual pressure and may remain filled for several minutes to several hours. In addition to the cap, the small intestine proximal to the point of obstruction is very often outlined by barium.

In the absence of any demonstrable extrinsic gastric pressure defect, it may be extremely difficult, from a purely objective standpoint, to differentiate a congenital extragastric anomaly such as a gastrohepatic band or persistent anterior mesogastrium from hypertrophic pyloric stenosis. In both instances, there will be incomplete filling or non-visualization of the duodenal cap. Intermittent hyperperistalsis may be encountered. However, the pyloric canal, if visualized, will appear normal in length and caliber. There is an absence of "shoulders" projecting into the antrum and also the "beak-like" projection toward the cap. The history will aid in arriving at the correct diagnosis, for with congenital bands, there may have been a feeding problem from the time of birth or shortly thereafter with a gradual increase in symptoms of vomiting as the infant grows, reaching a climax at the fourth to sixth week or even as late as three months and on rare occasion as late as ten months. This gradual and progressive increase in the severity of the symptoms is due to the fact that as the infant grows the fibrous bands remain practically stationary and thus exert a relatively greater pressure defect.

During the past two and a half years (January, 1940, to July, 1942), we studied the gastrointestinal tract of 50 infants according to the technique outlined. The severity of symptoms varied from that of projectile vomiting during or following each meal to that of occasional vomiting during or following a feeding. The age at the time of examination ranged from thirteen days to nine weeks—average, 6.3 weeks. The examination was usually started on the fourth

or fifth day of symptoms. There were 18 females and 32 males, a ratio of 1 to 1.8. The majority were sent for roentgen examination with a tentative clinical diagnosis of hypertrophic pyloric stenosis. In the remainder, a request was made to determine cause for continued intermittent vomiting after failure to completely control vomiting by antispasmodics and thick feedings.

In 12 infants, periodic vomiting was not influenced by thick gruel feedings and antispasmodics. They lost weight, became partially dehydrated and operative intervention, after adequate preoperative treatment, was decided upon. From a roentgenologic standpoint, all except 2 showed elongation of the pyloric canal with a diminution in caliber. The narrowing in some instances was such that the canal was represented simply by a "thread of barium," its length measuring 1.0 to 2.5 cm. or 3.0 cm. There was no cycle of normal motility, but rather almost constant ejection of small amounts of barium with each contraction wave during the first three or four hours, with an eventual prolonged emptying time of twelve to twenty-four hours. There was a direct relation between the degree of narrowing and elongation of the canal and the rate of gastric motility. In those cases with marked narrowing, as much as 80 to 90 per cent retention was encountered at the end of four hours and as high as 50 per cent at the end of twenty-four hours.

The duodenal cap was never completely filled in a single instance of uncomplicated hypertrophic pyloric stenosis. In most instances, it was visualized only by a few specks of barium and, due to the tremendously slow rate of motility, the small intestinal pattern appeared "thready," connecting sparsely scattered small clumps of barium.

One case with good visualization, complete filling of the cap, and a normal pyloric canal had a congenital duodenohepatic band completely obstructing the duodenum just above the ampulla of Vater (Fig. 10). This patient had bile-free vomitus.

Fig. 10. B. G., female, aged thirteen days. Intermittent vomiting since birth with gradual increase in severity of symptoms. Vomitus not bile stained. Stomach normal, cap filled readily, peristalsis shallow. No barium left the stomach during the first six hours. There was approximately 80 per cent gastric retention at the end of twenty-four hours. Operation—congenital duodenohepatic band running across second portion of duodenum just above ampulla.

Another case with poor visualization and incomplete filling of the cap had a normal pyloric canal but showed an extrinsic pressure defect running across the pyloric antrum, which at operation proved to be due to a congenital gastrohepatic band.

Operative Findings

Hypertrophic pyloric stenosis (8 males and 1 female)	9
Hypertrophic pyloric stenosis and volvulus of small gut (F)	1
Congenital duodenohepatic band (F)	1
Congenital gastrohepatic band (F)	1
Total	12

atonic; peristalsis was shallow, occurred at lengthy intervals, or was not encountered at all. At this "advanced stage," vomiting is not as severe and occurs less frequently than in the earlier stages—probably due to marked atonicity and refusal of formula by the infant which, as a rule, vomits only when part of a formula is introduced into a stomach already the seat of marked retention.

In the second group of 20 cases, the severity of the vomiting seemed to be far out of proportion to the degree of pyloric narrowing and elongation. There was vomiting either during or after practically every feeding of a formula of ordinary consistency, not influenced by antispasmodics, although controlled to a variable degree by thick feedings. On the roentgenogram, there was very slight, if any, narrowing of the pyloric canal, which did not exceed a length of 0.5 cm. They showed intermittent hyperperistalsis with an occasional reverse peristaltic wave resulting in regurgitation of the barium. The stomachs, as a rule, were orthotonic, there was not a marked degree of retarded gastric motility, and the cap was fairly well visualized. It was thought that these infants represented mild cases of pyloric muscle hypertrophy and that vomiting was due largely to a disturbed gastric motor function. The amount of gastric retention at the end of four hours ranged from 40 to 50 per cent. All of these cases were sufficiently controlled by expectant treatment so that neither dehydration nor nutritional disturbances ensued and symptoms gradually disappeared.

The third group, consisting of 18 cases, had mild episodes of vomiting, occurring at irregular intervals, but usually at the completion of a feeding. One had intermittent regurgitation during each feeding. This infant was later shown to have a megaesophagus (Fig. 11 and 12). Survey roentgenograms showed a marked gaseous distention of the stomach and small intestine, and roentgenoscopically one could demonstrate large gulps of air in the esophagus with resultant distention of the stomach

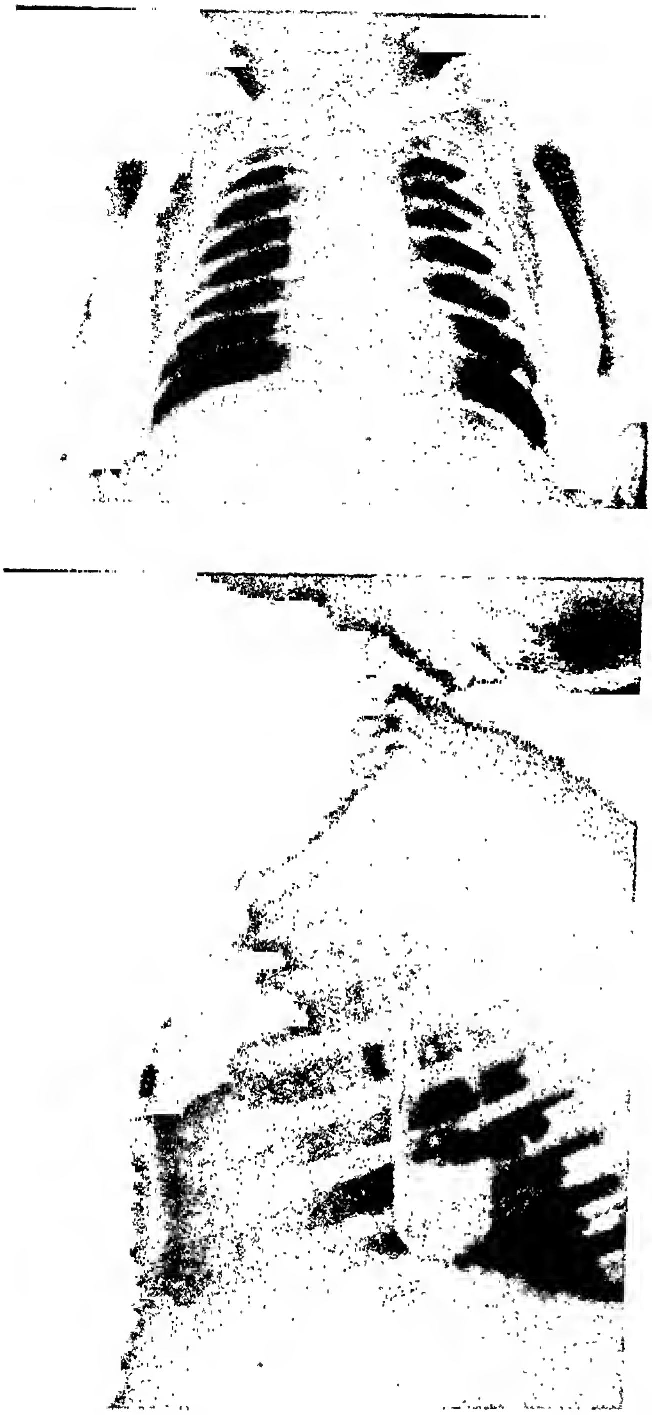

Fig. 11 and 12. S. D., male, aged four days. Regurgitation of formula with each feeding since birth—occasional vomiting. Note dilated air-filled esophagus, gas-distended cardiac end of stomach with fluid level.

In the group with marked pyloric obstruction, examinations made within several days of the onset of symptoms usually showed stomachs of the orthotonic type with intermittent hyperperistalsis. If symptoms persisted more than a week prior to the examination, the stomach was as a rule hypotonic and occasionally dilated and

Peristalsis was shallow, gastric motility retarded, but, as far as we could determine, the pyloric canal was within normal limits. As a rule, very little barium left the stomach during the first hour and at the end of two and a half hours there was approximately 50 to 60 per cent retention; at the end of four hours there was approximately 25 per cent retention. The stomach and small intestine showed abnormally large amounts of gas during the entire examination. Inadvertently, these patients had not been placed in the prone position either before or during the examination. All were re-examined one or two weeks later, and it was made certain that they were kept in a prone position both before and during the examination. This resulted in a marked reduction in the amount of gas in the stomach and almost complete elimination of gas from the small intestine. Under these conditions, normal motility followed with at least 80 to 90 per cent gastric evacuation at the end of two and a half hours.

However, in 2 cases, while the stomach was relatively free of gas, large amounts of gas still remained in the small intestine and the colon; the latter was markedly distended. Again we encountered delayed gastric motility with 50 per cent gastric retention at the end of four hours in 1 case and, in the other, approximately 90 per cent at the end of eight hours and at least 50 per cent at the end of twenty-four hours. Due to distention of the colon, the anal sphincter was investigated and found spastic. Stretching of the anal sphincter was begun. Two weeks later, a survey roentgenogram showed no gas in the small intestine and only a moderate amount in the colon after a period of four hours in the prone position. Re-examination with barium revealed normal gastric motility and emptying time, i.e., at least 75 to 80 per cent of the barium was evacuated at the end of two and a half hours. These 2 cases probably demonstrate the existence of a gastric inhibitory reflex of ileocolic origin, which disappeared following correction of anal sphincter spasm.

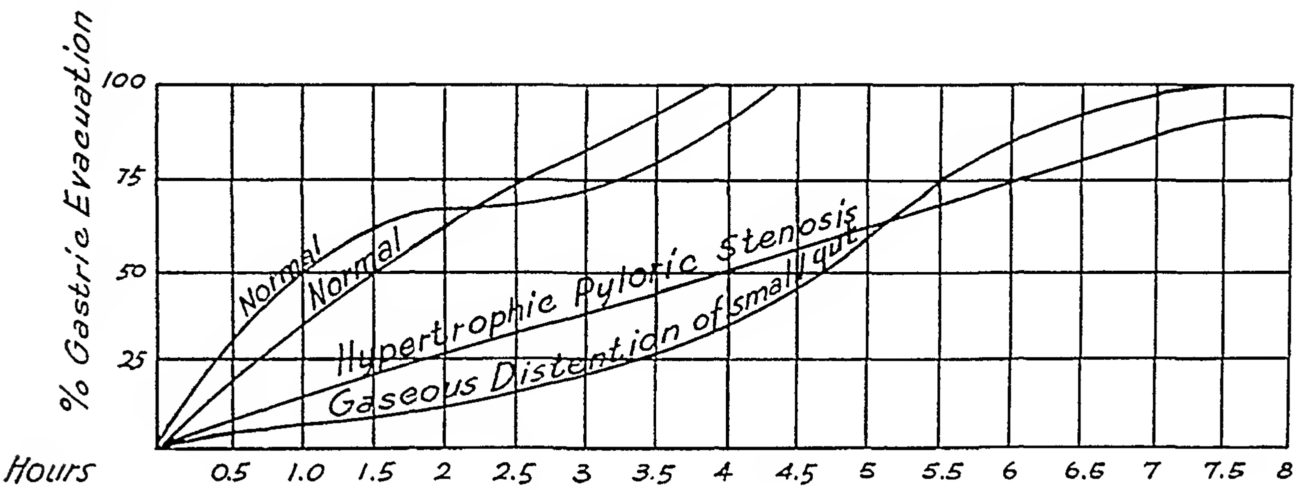

Chart I. Gastric motility rate normal; hypertrophic pyloric stenosis and gas-distended small intestine.

When the infant's stomach is orthotonic, the small intestine free of gas, no distention of the colon, and the motility rate is sufficient to completely fill the cap, we have accepted two and a half hours as the normal emptying time of the major portion of barium from the infant's stomach, i.e., 75 to 85 per cent. The final and complete emptying of the normal infant's stomach is so variable that it is of little or no diagnostic importance, for not infrequently traces are found ten to twelve hours or longer after ingestion. These cycles of gastric motility are apparently brought about by extraneous conditions, so that evaluation of the emptying time, without consideration of the "motility cycle," is misleading. On numerous occasions, motility did not really begin until the second or third hour

or later; then it proceeded normally—hence, we may have a four to six or eight hour emptying time in a perfectly normal stomach. Gaseous distention of the colon with an incompetent ileocecal valve may produce an intermittent ileus with corresponding reflex gastric inactivity and absent motility for several hours. Under these circumstances, a saline enema or simple deflation of the colon will almost immediately bring about normal gastric motor function and motility.

In our proved cases of advanced pyloric stenosis, the more rapid motility rate took place during the first three or four hours, followed by a much slower rate or complete gastric inactivity—requiring ten to twelve or more hours for complete evacuation.

The cases (20) interpreted as mild pyloric muscle hypertrophy had a pyloric canal not exceeding 0.5 cm. in length and an emptying time of four to four and a half hours. The cap was visualized fairly well in all these cases, and, in approximately one-half this number, gastric peristalsis was hyperactive, with the observance of an occasional reverse gastric peristaltic wave. In the remaining half, the stomach was atonic, enlarged, with never complete filling of the cap. These patients all did well with antispasmodics and thick gruel feedings; all were symptom free six months after initial examination. In all probability, the symptoms of vomiting were due largely to a disturbed gastric motor function. This group might include a large number of these cases in which subsidence of symptoms is ascribed to a gradual disappearance of the pyloric muscle hypertrophy. It is extremely doubtful whether true pyloric muscle hypertrophy with symptoms not controlled by thick gruel feedings and antispasmodics ever disappear spontaneously. While one may not be justified in making a diagnosis of moderate pyloric muscle hypertrophy based on the length of the pyloric canal, retarded gastric motility is certainly not a reliable index due to the numerous extra-gastric influences on the rate of gastric evacuation, and in this particular group regurgitation was frequently associated with reversed gastric peristalsis seen roentgenoscopically.

With complete, incomplete, or recurrent obstruction distal to the pyloric ring, the stomachs were usually large, atonic, with shallow peristaltic waves, if any, and a dilated intestine proximal to the point of obstruction. There was no period of normal gastric motility, and the amount of gastric retention was, in general, proportional to the degree of stenosis.

FINDINGS IN PYLORIC MUSCLE HYPERTROPHY

1. Early—a. Stomach orthotonic occasionally hypertonic. b. Intermittent gastric hyperperistalsis.
2. Late—a. Hypotonic to atonic. b. Feeble, shallow peristaltic waves limited almost entirely to the pyloric region.
3. A constant, unchanging, narrowed caliber of pyloric canal with elongation beyond 0.5 cm.
4. If pyloric canal cannot be demonstrated, one should look for a "beak-like" projection of barium pointing toward the cap from mid-portion of antrum.
5. The demonstration of "shoulders" convexly directed toward the pars media in well advanced cases.
6. Visualization of the cap simply by specks of barium or partial filling (never complete filling of cap).
7. Absence of cyclic motility and prolonged emptying time (50 per cent or less evacuated at the end of four hours, not influenced by antispasmodics.)

OBSTRUCTIONS DISTAL TO PYLORIC RING

1. Atonic and usually enlarged stomach.
2. Absence of peristaltic activity.
3. Normal pyloric canal.
4. Complete filling and good visualization of cap.
5. Stasis and dilatation of small intestine proximal to point of obstruction and collapsed intestine distal to this point.

6. Distended loop of small intestine limited to one part of the abdomen in the erect position.

CONCLUSION

In the absence of intracranial injury or pulmonary infection it is our belief that the roentgen examination has a definite place in the investigation of the infant's gastrointestinal tract in the presence of vomiting with clinical findings suggestive of pyloric stenosis. We can demonstrate the degree of pyloric stenosis or locate with a reasonable degree of accuracy the point of atresia or extrinsic pressure distal to the pyloric ring and thus guide the surgeon in his operative approach. The vast majority of these cases do not call for any emergency operative intervention and, if carefully studied, we believe one can largely separate the medical from surgical cases. One must keep in mind the cyclic activity and motility of the infant's stomach and its susceptibility to various extraneous influences and not rely solely on the rate of gastric motility as a very important criterion in pyloric stenosis. Of the 38 cases not operated upon, the symptoms in 18 were apparently due to an adynamic "ileus-like" state of the small intestine, largely the result of aerophagia. They respond readily to treatment directed to the elimination and prohibition of gas accumulation in the stomach and small intestine.

The 20 cases in which there might have been a moderate hypertrophy of pyloric muscle, with the canal not elongated beyond 0.5 cm., the symptoms were due largely to a disturbed gastric motor function, easily controlled by thick gruel feedings when extraneous influences are eliminated. These non-operative cases might include a large number in which the subsidence of symptoms has been attributed to a gradual disappearance of the hypertrophied mass of pyloric muscle. All were symptom free two to six months following the examination.

Those cases which will most likely require surgery have an enlarged, slightly atonic stomach, a narrow pyloric canal, elongated beyond 0.5 cm. and more than 50 per cent gastric retention under ideal conditions (usually 70 to 80 per cent) at the end of four hours.

REFERENCES*

1. Brennemann. Practice of Pediatrics. Vol. III., Chap. 5, p. 9.
2. Calvin, J. K., and Denenholz, B. J. Value of roentgenography in congenital pyloric stenosis. *Arch. Pediat.*, 1941, *58*, 26–39.
3. Ford, N., Ross, M. A., and Brown, A. Primogeniture as an etiologic factor in pyloric stenosis. *Am. J. Dis. Child.*, 1941, *61*, 747–751.
4. Haas, S. V. Congenital hypertrophic pyloric stenosis. *J. Mt. Sinai Hosp.*, 1941, *7*, 411–422.
5. Johnstone, A. S. Radiological sign of pyloric stenosis. *Brit. J. Radiol.*, 1943, *16*, 169–170.
6. Mack, H. C. History of hypertrophic pyloric stenosis and its treatment. *Bull. Hist. Med.*, 1942, *12*, 465; 595; 666.
7. McLanahan, S. Determination of pyloric patency following Fredet-Rammstedt operation for congenital hypertrophic pyloric stenosis. *Surg., Gynec. & Obst.*, 1941, *73*, 874–875.
8. Meredith, F. W. Report of 137 cases of pyloric stenosis. *Pennsylvania Med. J.*, 1940, *43*, 1686–1687.
9. Paterson, D., Dobbs, R., Barrington-Ward, L., and Levi, D. Discussion on pyloric stenosis in infancy. *Proc. Roy. Soc. Med.*, 1941, *35*, 49–60.
10. Robertson, D. E. Congenital pyloric stenosis. *Ann. Surg.*, 1940, *112*, 687–799.
11. Runström, G. Roentgen-anatomical appearance of congenital pyloric stenosis during and after manifest stage of disease. *Acta paediat.*, 1939, *26*, 383–433.
12. Szilagyi, D. E., and McGraw, A. B. Problems of infantile pyloric stenosis with particular reference to surgical treatment. *Surgery*, 1943, *13*, 764–818.
13. Wallgren, A. Incidence of hypertrophic pyloric stenosis. *Am. J. Dis. Child.*, 1941, *62*, 751–756.
14. Wilkinson, S. A. Medical management of pyloric obstruction. *Surg. Clin. North America*, 1941, *21*, 735–741.

* Some references to the older literature are to be found in Holt's Diseases of Infancy and Childhood, p. 417.

GASTRIC VOLVULUS AND OTHER ABNORMAL ROTATIONS OF THE STOMACH

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GASTRIC volvulus is an abnormal rotation of the stomach. Schatzki and Simeone[3] point out that any changes in position of the stomach must be by some form of rotation and, therefore, rotation, *per se*, is not necessarily volvulus, as in the case of high lying stomachs of obese individuals. They class the "upside down" appearance of the high stomach commonly found associated with eventration of the diaphragm as one example of the same phenomenon. However, true volvulus may occur in the presence of eventration (see Case VI). A rotation of the stomach, reaching or closely approaching 180 degrees, which spontaneously reduces itself, is reducible by manipulation, or can reasonably be assumed to be the result of injury, will be considered true gastric volvulus. Other abnormal rotations are those which are not subject to reduction either spontaneously or manually, and which can be assumed to be variations on a basis of congenital anomalies.

The terminology of classification of this unusual condition is conflicting. Singleton[5] states that "Gastric volvulus may be defined as an abnormal anterior or posterior rotation of almost all of the stomach about either the coronal or sagittal axis of the body. The stomach being fixed by the gastro-phrenic ligaments above and the peritoneum covering the second portion of the duodenum below, is limited in mobility between these fixed points only by the length of the gastro-hepatic omentum and may be displaced within these limits by extrinsic pressure from whatever cause. Pressure displacement of the stomach is, therefore, very common, but actual rotation of a part or almost all of the stomach is relatively rare and would seem to require unusually long gastro-hepatic and gastrocolic mesenteries to allow of its occurrence." He classes volvulus as to type: "(a) Organo-axial. Rotation of the stomach upward around the long axis of the stomach, i.e. around the coronal plane. (b) Mesentero-axial. Rotation of the stomach from right to left, or left to right, about the long axis of the gastro-hepatic omentum." Volvulus, according to Becker,[1] as reported by Morrison,[2] is an organo-axial rotation of the stomach, and torsion is a twist of the stomach. Torsion falls into Singleton's classification as mesentero-axial volvulus. Shanks, Kerley and Twining[4] state that in one type of volvulus, "the stomach folds itself on the coronal axis," and in the other type there is torsion of the fundus. For the purposes of this paper, volvulus will be divided into (1) organo-axial volvulus (rotation on the coronal axis) and (2) torsion volvulus.

In acute gastric volvulus, the rotation is so great that the blood supply of the stomach is interfered with, and immediate surgery is indicated. None of the cases presented here fall into this group.

The following cases, because of the characteristic roentgen findings and interesting clinical pictures, are believed worth reporting.

REPORT OF CASES

CASE I. (Case of Dr. V. W. Archer.) C.D.N., white, female, aged twenty-eight. The patient had previously been seen with varied complaints believed to be on a psychoneurotic basis. Her chief complaint was indigestion and burning in the epigastric and substernal regions. She was quite obese, her weight was 244 pounds, height 5 ft. 5 in. Although she was a nullipara there were striae over her abdomen. Hemoglobin was 85 per cent (Dare) but the

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feces and vomitus gave a four plus reaction to the benzidine test. Roentgenoscopic examinations showed the antrum twisted in relation to the body of the stomach. As a result of the torsion, the duodenal bulb pointed to the left (Fig. 1). With a few days of bed rest the symptoms subsided. Two weeks following this episode the stomach was negative. Four months later the stomach presented a cascade appearance which did not resemble either type of volvulus and was otherwise negative. There were no similar episodes over the period of one year following the first examination, during which time the patient had been on a reducing diet and had lost a good deal of weight.

Comment. The excessive degree of twisting, as demonstrated by the pattern of the rugal folds and the position of the bulb (Fig. 1) and the spontaneous reduction are consistent with the diagnosis of torsion volvulus.

In obese individuals a somewhat similar appearance is sometimes demonstrated in normal high lying stomachs. The minor twisting of the rugal pattern and the normal position of the bulb differentiate torsion volvulus from a normal high lying stomach.

Attention has been called to the difference in appearance between gastric volvulus and a cascade stomach. Intra-abdominal pressure due to obesity is believed a contributory factor in this case.

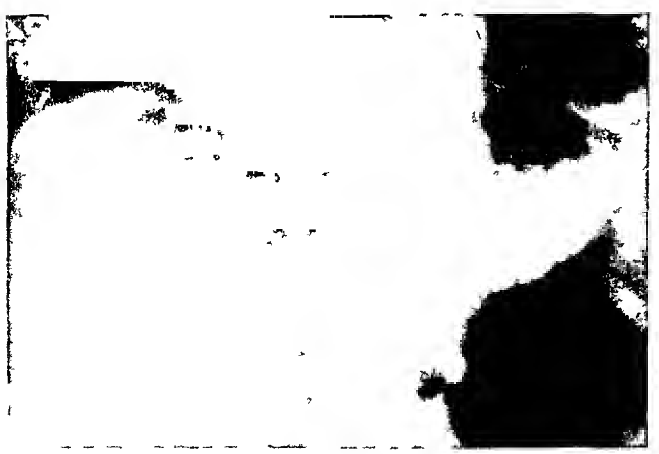

Fig. 1. Case 1. Torsion volvulus. The twisting of the stomach on itself, demonstrated by the pattern of the rugal folds, occurs at the junction of the antrum and the pars media. The bulb is pointed to the left.

Fig. 2. Case II. Organo-axial volvulus. The rotation of the greater curvature into a superior position causes a relative shortening of the stomach and a pull on the bulb, causing the antrum and the bulb to point downward.

Case II. (From the files of University Hospital, Charlottesville, Virginia.) M.B.F., white, female, aged forty-two. For three years, at intervals of from one to three months, there had been attacks of nausea, vomiting and epigastric pain but no belching or hematemesis. Each episode was sudden and there were no premonitory symptoms. Symptoms were severe but undulating in nature, being first severe than gradually fading, this sequence being repeated several times in each attack. At no time during an attack did the pain disappear completely. The pain was localized in the epigastrium just below the xiphoid and did not radiate. It felt "as if something was squeezing down deep inside." In the months just previous to admission, attacks gradually became more severe, more frequent, and lasted as long as ten days. It is worthy of note that during these symptomatic periods vomiting occurred after solid food intake but not after intake of fluid alone. Appetite

was excellent except during a severe episode.

Two and one-half years prior to this admission, roentgen studies of the stomach had been negative. On this admission the diaphragm appeared normal on roentgenoscopic examination. In the upright position, barium flowed through the cardiac orifice into a large posterior gastric pouch. The pars media was rotated upward so that the greater curvature was above the lesser and it was superior to the level of the cardia. After this pouch filled the barium

Fig. 3. Case II. Organo-axial volvulus. Barium enema showing the displacement of the splenic flexure upward and to the right due to the pull on the gastrocolic ligament by the rotated stomach.

poured into the rest of the stomach so that there were two fluid levels. The rotation of the greater curvature to a superior position in relation to the lesser caused a pull upward on the antrum and bulb which pointed downward. The roentgenogram in the prone position confirmed the rotation (Fig. 2). A barium enema demonstrated a pulling, cephalad and to the right, of the splenic flexure of the large bowel (Fig. 3). An exploratory laparotomy was performed and no abnormality of the stomach was found. Six weeks later a gastrointestinal series was entirely negative. Within the next year there had been five episodes similar to the previous attacks.

Comment. This case is believed to represent a typical picture of recurrent, chronic gastric volvulus, with the history typical as well as the roentgen findings. It is notable that the patient did not belch during attacks and it is thought that this was due to the dependent position of the junction of the cardiac orifice which prevented the stomach bubble from coming in contact with the cardiac end of the esophagus. Relaxed intra-abdominal ligaments are believed to be a contributory factor in the production of the abnormal rotation of the stomach in this patient.

Case III. (From the files of the University Hospital, Charlottesville, Virginia.) H.R.W., white, male, aged forty-two. This patient was admitted because of nausea, vomiting, epigastric discomfort, and progressive weakness of five months' duration. There had been a weight loss of 56 pounds. The clinical picture was clouded since there had been a recurrent diarrhea, nausea, and vomiting with fever three years previously, which was diagnosed as nontropical sprue. At the initial examination the diaphragm was normal. No abnormalities of the stomach were noted. The duodenum, from the bulb to the ligament of Treitz, was somewhat dilated and there was a low grade obstruction at this point. Reverse peristalsis alternated with normal peristalsis from the bulb to the ligament of Treitz in the upright, supine, and prone positions. There was tenderness at the point of obstruction. At six hours it was decided to re-examine the stomach and duodenum. On administration of additional barium, in the upright position, the meal was seen to enter a pocket at the cardiac end of the stomach. When this pocket filled the barium flowed up under the diaphragm and to the right, to form a loop as it flowed into the antrum which was drawn upward by a rotation of the stomach, causing the bulb and antrum to point downward. There was no delay at the ligament of Treitz at this examination. A barium enema showed a markedly redundant and dilated large bowel throughout. Otherwise, no abnormalities were noted in the large bowel. Four days later roentgen examination no longer showed the volvulus and again showed the delay at the ligament of Treitz.

Comment. This case of chronic gastric

volvulus demonstrated the "loop" effect sometimes seen when the barium first reaches the stomach. This effect is best seen with the patient upright, in the posteroanterior position before the fluoroscopic screen. The severe primary weight loss and the atonic redundant colon are believed contributory factors in the production of volvulus in this case. Shanks, Kerley, and Twining call attention to the unusual evanescent quality of gastric deformities due to the colon.

Case iv. (From the files of Holston Valley Community Hospital, Kingsport, Tennessee.) H. L., white, male, aged fifty-four. The patient was well until six months previous to examination, at which time he began to have constant nausea with discomfort in the epigastrium and para-umbilical area. He vomited several times. There was no hematemesis. Belching gave some relief. After this episode, which cleared up spontaneously, the patient was well until one month prior to examination, when he again developed nausea and vomiting. There was rapid weight loss and the patient became cachetic in appearance. His abdomen was almost constantly distended.

On roentgen examination the diaphragm was normal. The barium meal flowed into the stomach and was seen to make a loop in the

Fig. 4. Case iv. Organo-axial volvulus. The loop at the cardiac end of the stomach is demonstrated. The greater curvature of the stomach lies in a superior position. The antrum is pulled upward and the bulb points downward.

Fig. 5. Case iv. Organo-axial volvulus. An air contrast study of the large bowel showing the unusual degree of redundancy.

cardiac portion. The greater curvature was rotated superiorly and the bulb and antrum were drawn upward; the pull of the gastrohepatic ligament caused them to point downward (Fig. 4). Except for this organo-axial rotation, no abnormalities were noted in the stomach. A large collection of gas in the colon, especially in the splenic flexure, was noted. A barium enema, which required twice the usual amount of barium mixture, showed a tremendous, redundant colon (Fig. 5). A re-examination of the stomach, following enemas, showed the stomach no longer rotated.

Comment. This case of chronic organo-axial volvulus is associated with a very redundant colon. The transient quality of this type of abnormal rotation, associated with abnormalities of the large bowel, was again demonstrated.

Case v. (From the files of University Hospital, Charlottesville, Virginia.) B.E.L., white, male, aged sixty-one. The patient was admitted following a four day history of nausea and repeated vomiting, but no hematemesis or tarry stools, associated with burning, cramping

Fig. 6. Case v. Organo-axial rotation of the stomach. High mid-transverse colon, in anterior hepatodiaphragmatic interposition, associated with the organo-axial rotation of the stomach.

epigastric pain. Although the pain was chiefly epigastric, it had occurred in both flanks and both upper quadrants and on one occasion had radiated to the shoulders. Until this episode there had been no gastric symptoms for over twenty years.

Roentgen examination showed a normal diaphragm. The stomach was rotated so that the greater curvature lay in a superior position, the antrum and bulb pointed downward. A barium enema showed the mid-transverse colon displaced upward in partial hepatodiaphragmatic interposition (Fig. 6). After several weeks in the hospital there was a remission of symptoms. There is no follow-up.

Comment. This case does not meet all of the criteria of a gastric volvulus since a negative roentgen examination of the stomach was not obtained. However, it is believed an organo-axial volvulus, associated with an unusual position of the colon.

Case vi. (From the files of University Hospital, Charlottesville, Virginia.) H.M.J., colored, female, aged thirty-eight. There was a history of intermittent abdominal pain for four years. The chief complaint was "stomach trouble" with mild aching and tenderness in the epigastrium. The abdomen was distended. There had been no episodes of nausea and vomiting.

Roentgen examination showed an eventration of the diaphragm on the left. On examination of the upper gastrointestinal tract, the pars media was rotated to a position superior to the level of the cardia and antrum. The antrum was pulled upward along with the bulb, the pull of the gastrohepatic ligament causing the bulb and antrum to point downward. The esophagus entered the stomach in a dependent position. Two fluid levels were well demonstrated in the stomach, one in the cardia and one in the antrum (Fig. 7). The findings were unchanged during three examinations over a period of two months until during the third examination, in the prone position, the stomach resumed its normal position. Three months later the stomach initially presented a rotated appearance and it was again determined that, in the prone position, it was subject to reduction to normal position.

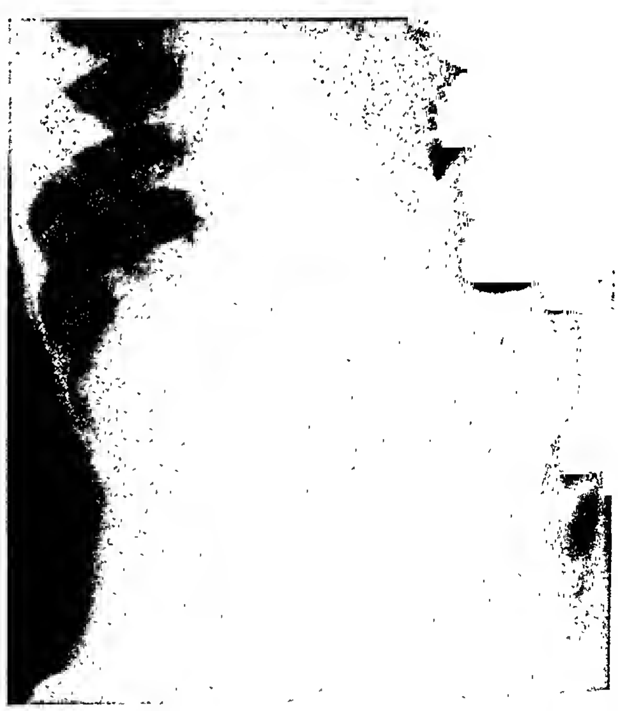

Fig. 7. Case vi. Organo-axial volvulus. The rotation of the greater curvature to a superior position, two separate fluid levels, one in the cardiac portion and one in the antrum of the stomach, are well demonstrated. The antrum is pulled up causing the bulb to point downward. In the prone position this stomach resumed its normal position upon occasion.

Comment. It is believed that the organo-axial volvulus was concomitant with diaphragmatic eventration. When intra-abdominal pressure on the stomach was lessened, in the prone position, the stomach would, upon occasion, resume its normal position. This is reported as a case of true chronic gastric volvulus, associated with eventration of the diaphragm.

Case vii. (Case of Dr. V. W. Archer.) B. A., white, male, aged sixty-five. This patient, who was quite obese, was examined because of a secondary anemia of unknown etiology. At the first examination the stomach was high, small, and hyperactive. It emptied quickly and no abnormalities were found. At a subsequent examination a small diaphragmatic hernia was demonstrated, and the stomach was rotated so that its greater curvature was in a superior position, its lesser curvature in an inferior position, and the antrum pulled upward. The bulb and antrum pointed downward (Fig. 8).

Fig. 8. Case vii. Organo-axial volvulus. The greater curvature is seen rotated above the lesser curvature. A portion of the pars media projects through a small diaphragmatic hernia.

In addition to a large, redundant, spastic colon, a filling defect was demonstrated in the cecum. At operation a carcinoma of the cecum was found.

Comment. A case of organo-axial volvulus which apparently was unconnected with the patient's symptoms has been presented. Obesity, redundancy of the colon, and diaphragmatic hernia all may have been etiological factors in the production of this abnormal rotation.

Case viii. (From the files of Lawson General Hospital, Atlanta, Georgia.) White male, aged twenty-five. This patient was in an automobile accident which caused three ribs to be fractured. He immediately developed difficulty in breathing. The line of demarcation between the left lung and abdominal viscera on the left was high and a tentative diagnosis of traumatic diaphragmatic hernia was made. When first seen here his complaint was of vague discomfort in the epigastrium when walking. His induction roentgenogram showed a normal left hemidiaphragm. Gastrointestinal studies showed the esophagus entering the cardia in a dependent position. The greater curvature of the stomach was rotated above the lesser. The antrum was pulled upward and the bulb pointed downward (Fig. 9). The colon, except for an unusually high splenic flexure, was normal in position. Since roentgenoscopic study with barium in the stomach in the routine Trendelenburg position had failed to confirm the presence of a traumatic hernia, air was injected into the peritoneal cavity and an upright roentgeno-

Fig. 9. Case viii. Organo-axial volvulus. The cardia is in a dependent position, the greater curvature is superior to the lesser curvature. The antrum is drawn upward and the bulb points downward. The abnormal rotation of the stomach is associated with a traumatic herniation of the diaphragm.

gram of the chest made just after this showed a pneumothorax (Fig. 12). (Several hundred cubic centimeters of air must be injected for this method to be successful. Previously a lesser

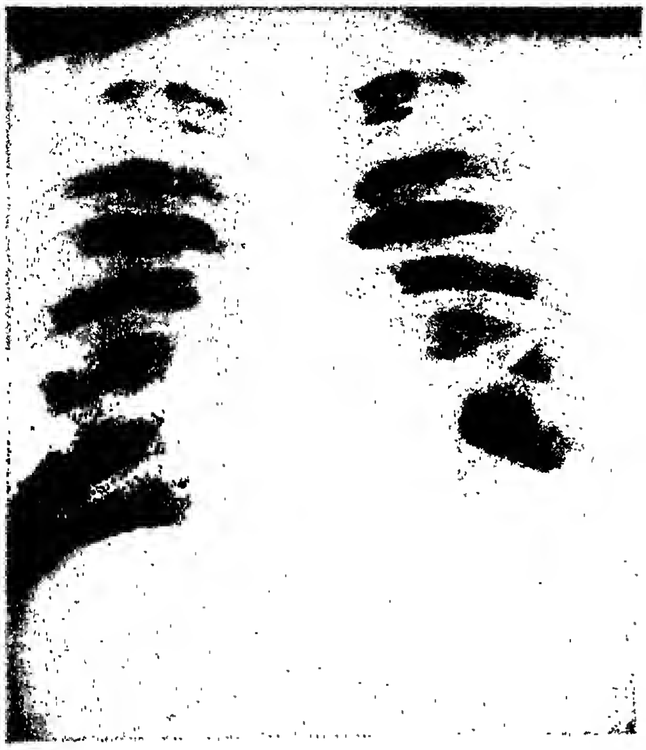

Fig. 12. Case VIII. Traumatic hernia of the diaphragm. Roentgenogram showing pneumothorax following the injection of air into the peritoneal cavity. The stomach [illegible] is seen in the left pleural cavity.

[illegible]

Case IX. (From the files of Lawson General Hospital, Atlanta, Georgia.) White male, aged nineteen. The patient had suffered occasional twinges of pain in the left axilla for the past several years. Five months before admission he was struck by a truck. He was unconscious for some time. The left patella and fibula were fractured. Two and one-half months following the accident, and one and one-half months following discharge from the hospital, during which time there had been no gastric symptoms, he suddenly developed a severe cramping pain in the upper abdomen. This persisted unchanged for two days and then disappeared. One month later there was a recurrence of symptoms. The pain subsided in thirty-six hours. Roentgenographic and roentgenoscopic examination of the chest showed what was interpreted as a high left hemidiaphragm which moved slightly but synchronously with the right leaf of the diaphragm on respiration.

On administration of the barium meal the cardiac orifice was in a dependent position. Barium flowed upward into a stomach which

[illegible]

was rotated so that the greater curvature was superior to the lesser, and the pars media was above the level of both the cardiac end and the antrum. The antrum and bulb pointed downward (Fig. 11). Associated with this was displacement of the colon in the area of the splenic flexure (Fig. 12). During his stay in the hospital the patient suffered one severe episode of abdominal pain, associated with nausea and vomiting, which lasted a few hours. After this the patient was asymptomatic but the stomach was seen to remain rotated at a subsequent examination.

Comment. A case of organo-axial rotation of the stomach, associated with a probable diaphragmatic eventration, has been presented. Even though the stomach remained rotated, gastric symptoms were intermittent. This case illustrates the difficulty in making a differential diagnosis between eventration and traumatic hernia of the left hemidiaphragm. The usual Trendelenburg position failed to reveal evidence of traumatic herniation and additional diagnostic studies (such as were used in Case VIII) were not carried out.

Fig. 12. Case IX. Organo-axial rotation. The unusual twisting of the large bowel associated with the abnormal rotation of the stomach is demonstrated.

Case X. (Case of Dr. P. L. Fisher.) E. R., white, male, aged fifty-four. Three years previous to the gastrointestinal series the patient had been seen and was complaining of sour stomach, belching, and pain in his stomach when it was empty. The chief complaint at the time of this examination was of pain in the stomach, nervousness, and burning. There was some abdominal tenderness.

Fig. 13. Case X. Organo-axial rotation. The abnormal rotation of the stomach under the high left diaphragm is demonstrated. The greater curvature is superior to the lesser. The esophagus enters in a dependent position, the antrum and bulb point downward.

Roentgen examination showed the left hemidiaphragm very high and there was no history of injury to suggest traumatic herniation. The esophagus entered the cardia in a dependent position. The cardia and antrum were below the level of the pars media, which was rotated upward so that the greater curvature was superior to the lesser curvature. Barium first filled the cardiac end of the stomach and finally poured over into the antrum (Fig. 13). Two fluid levels were seen, one in the antrum and one in the cardia. Unlike a cascade stomach in which the cardiac portion forms a pouch hanging down, the body of the stomach was superior to the cardiac portion.

Comment. This is a case of organo-axial rotation of the stomach associated with eventration.

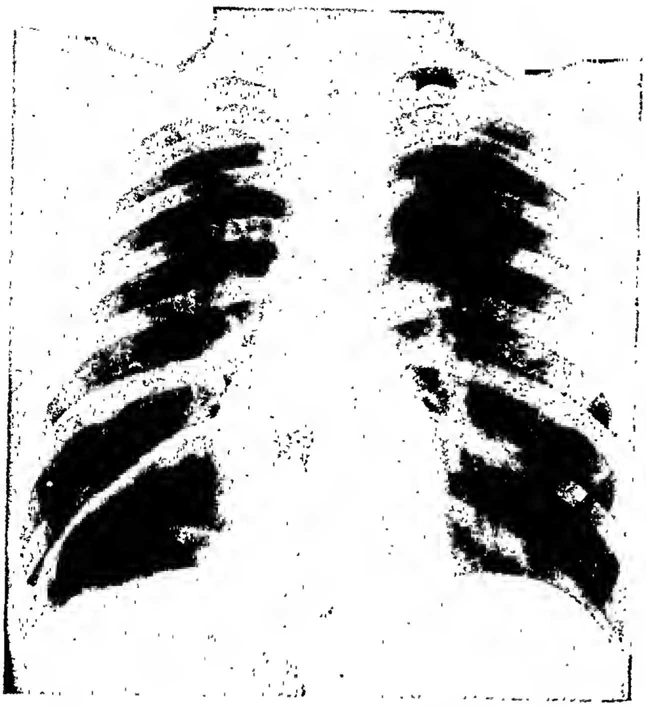

Fig. 14. Case xi. Right-sided thoracic stomach. A large stomach bubble is seen in the right side of the thoracic cavity above the diaphragm. (Note absence of stomach bubble under the left hemi-diaphragm.)

Fig. 15. Case xi. Right-sided thoracic stomach. Right anterior oblique position: The stomach is seen to lie above the right leaf of the diaphragm in an anteromedial position. (Film retouched.)

Case xi. (From the files of Lawson General Hospital, Atlanta, Georgia.) White male, aged twenty-seven. This patient, who was 5 ft. 10 in. in height and weighed 150 pounds, had suffered "stomach trouble" for from six to eight years. There had been a swelling under the short rib on the right, at irregular intervals, which was not influenced by type or quality of food intake. This swelling was associated with a constant pain in the right upper quadrant of the abdomen, and a "quivering of my stomach and my heart beats fast." Nevertheless, for the past

Fig. 16. Case xi. Right-sided thoracic stomach. The stomach lies herniated through the foramen of Morgagni, superior to the right hemidiaphragm. The colon is incompletely rotated. The fold of bowel at the splenic flexure is pulled somewhat to the right by what is believed to be an unusually long gastrocolic ligament.

two years he had been in the Army and able to perform his military duties. There was no history of trauma which could enter into the etiology.

Roentgenological studies were made which showed a large pocket of gas in the thoracic cavity at the right base against the lower border of the heart, displacing the anterior portion of the lower lung upward, posteriorly, and laterally. There was no stomach bubble under

the left hemidiaphragm (Fig. 14). In the left anterior oblique and lateral roentgenograms, the gas pocket was seen to lie anteriorly and above the diaphragm (Fig. 15). A gastrointestinal series showed the esophagus in normal position down to a point 4 cm. above the diaphragm where it turned to the right and sharply upward and was attached to the stomach which lay in the thoracic cavity in the position of the stomach bubble described above. To attain this position the stomach had undergone marked rotation (Fig. 16). A barium enema showed an unusual degree of separation of the stomach from its usual anatomical position with the transverse colon. The colon was not completely rotated allowing a large fold of bowel to be displaced to the right at the splenic flexure.

Comment. An abnormal gastric rotation of a right-sided thoracic stomach (not associated with situs inversus) has been presented. The findings are consistent with a congenital herniation of the stomach through the foramen of Morgagni. Associated with this was an abnormal position of the colon.

DISCUSSION

In all of the cases presented relaxed intra-abdominal attachments are believed to have been present. Obesity, trauma, marked weight loss preceding gastric rotation and anomalous development were varying factors in the etiology of most of the abnormal gastric rotations. A large, redundant, or abnormally situated colon was a feature in several cases of true volvulus. Attention has been called to the transient nature of some of these. Eventration of the left hemidiaphragm was present in 3 cases, in 1 of which there was a true volvulus. In 2 cases of volvulus there was a herniation of the diaphragm, 1 traumatic, the other a small herniation in an obese individual. An unusual congenital variation, a right-sided thoracic stomach, congenitally herniated through the foramen of Morgagni, has also been reported.

Symptoms, while not characteristic, were present in all cases but one, in which case there were none referable to the gastric rotation, which was fleeting in character. In all of the other cases there was discomfort or pain in the epigastrium. In 6 cases there was nausea and vomiting. In several with true volvulus there was a history of similar attacks previously, with a complete remission of symptoms between attacks. Hematemesis and significantly positive benzidine tests on feces were present in only 1 case. Marked weight loss, directly attributable to the rotation of the stomach, was present in only 2 patients.

The characteristic findings in various rotations of the stomach, usually best seen in the upright, posteroanterior position, before the fluroscopic screen, have been described and illustrated. While in some cases the colon is displaced with the stomach, or vice versa, it is interesting to note that in 2 cases there was an extremely long gastrocolic ligament (Cases VIII and XI). It is obvious that in cases of true volvulus the finding may be missed unless the patient is examined during an attack. When there is an eventration of the left hemidiaphragm there may be an organo-axial rotation which is not true volvulus, but true volvulus does occur in the presence of eventration (Case VI).

The differential diagnosis between eventration and herniation of the diaphragm is important since, in the presence of herniation, a repair of the diaphragm, as in 1 case presented (Case VIII) both relieved symptoms and caused the stomach to return to a normal position. In carefully selected cases it is possible that surgery may be helpful in restoring the stomach permanently to a normal position with relief of symptoms.

SUMMARY AND CONCLUSIONS

1. Gastric volvulus implies an abnormal rotation of the stomach of, or approaching, 180 degrees which is not a congenital variation and which is subject to reduction.

2. There are two distinct types of volvulus, organo-axial, the most common, and torsion type, each giving a characteristic roentgenological appearance.

3. Organo-axial volvulus should be differentiated from other abnormal rotations of the stomach, and torsion volvulus from a high lying stomach in the presence of obesity. The differential diagnosis has been discussed.

4. There is little or no similarity between a cascade stomach and gastric volvulus.

5. Attention has been called to methods which may be used in differentiating between an eventration of the left hemidiaphragm and traumatic herniation (Case VIII).

6. Etiology and symptomatology have been discussed.

7. One case of torsion type volvulus, six of organo-axial volvulus, one believed to be organo-axial volvulus, two abnormal rotations, which were constant and associated with eventration of the diaphragm, have been reported. In addition, one congenitally right-sided thoracic stomach (not associated with situs inversus) herniated through the foramen of Morgagni, has been reported.

I am especially indebted for help in writing this article to V. W. Archer, M.D., University Hospital, Charlottesville, Virginia; to various members of the staff of the University Hospital, Charlottesville, Virginia, and of Lawson General Hospital, Atlanta, Georgia, as well as to P. F. Fisher, M.D., Tacoma Hospital and Sanatorium, Greenville, Tennessee, who granted me permission to include his case.

REFERENCES

1. Becker. Ueber die Magenverschlingung. *Arch. f. klin. Chir.*, 1927, *145*, 203–232.
2. Morrison, W. A. Torsion and volvulus of the stomach. *Surg., Gynec. & Obst.*, 1931, *52*, 871–874.
3. Schatzki, R., and Simeone, F. A. Volvulus of the stomach. *Am. J. Digest. Dis.*, 1940, *7*, 213–217.
4. Shanks, S. C., Kerley, P., and Twining, E. W., editors. A Text-Book of X-Ray Diagnosis. H. K. Lewis & Co., Ltd., London, 1938, Vol. II, p. 111.
5. Singleton, A. C. Chronic gastric volvulus. *Radiology*, 1940, *34*, 53–61.

OSTEOCHONDRITIS DISSECANS OF THE SUPRATROCHLEAR SEPTUM OF THE HUMERUS*

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SIX cases of osteochondritis dissecans in the intra-articular portion of the supratrochlear septum have been observed by us among young adult males during the past two years. Any known antecedent injury was commonly trivial; disability was the most prominent complaint. Of these cases, 5 have been operated upon with consequent confirmation of the diagnosis and relief of symptoms. Five have been considered suitable for reproduction.

Pfitzner[14] (1891), in his study of the sesamoid bones, described a condition at the elbow under the term "sesamum cubiti" which we believe has been subsequently used in error to describe the lesion under consideration.

Reports of but 6 other cases have been found in the literature since the advent of roentgen rays as diagnostic means. Hirsh,[6] Grauer,[5] Winckler,[16] Atsatt,[1] Kleinberg,[8] and Burman[3] each described a single case of a separate nucleus of bone located either in the supratrochlear septum or extruded into the elbow joint proper. Although an associated defect was present in the supratrochlear septum, the concept of the ossicle as a sesamum cubiti was generally entertained. This supposed sesamoid was thought to become intra-articular by some means, and in one instance was believed to have been pressed into a pre-existing supratrochlear foramen.[6] In commenting on Grauer's case, Köhler[10] doubted that the ossicle was either an accessory epiphysis or a sesamum cubiti and suggested that further anatomical study might shed light on the matter.

Histopathologic findings were not recorded in any of the reported cases although in 3 instances the ossicle was removed.[1,5,16] In none was a definite occupational predisposition established; trifling injuries preceded symptoms in the majority of cases.

As a result of the increasing use of the diagnostic roentgenogram, we believe that a sesamum cubiti, more properly termed "patella cubiti," does occasionally appear as an inconstant sesamoid in the triceps tendon.[7,9,13] This is entirely independent and different from osteochondritis dissecans of the supratrochlear septum.

PREDISPOSING ANATOMICAL FEATURES

The supratrochlear septum, usually a thin plate of bone in the distal humerus, lies between the medial and lateral supracondylar ridges just above the trochlea. It separates the coronoid fossa anteriorly from the olecranon fossa posteriorly. The lower portion of the septum is intra-articular on both the anterior and posterior surfaces.[4] Although commonly a complete osseous plate of varying thickness, thinnest at the base, it may in the process of development become perforated to form the "supratrochlear foramen."[11] This variant is said to be less frequent in the more highly developed mammalia and even among the more civilized humans than the aboriginal (Miller, quoted by Hirsh). It is not present at birth nor in the early years before the fossae and processes of the ulna approach their mature form, although such is said to have been observed as early as the seventh year. As the humerus develops, a possible disturbance of local blood supply may ac-

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count for the loss of continuity resulting in a supratrochlear foramen in one and the development of the nucleus of an osteochondritis dissecans in another. Such a vascular disturbance, perhaps incident to minor traumata, would conform to the rather widely accepted theory of the etiology of osteochondritis dissecans in other joints. We have observed either a tion at the knee, in which a long cruciate spine is commonly associated with an osteochondritis dissecans of the medial femoral condyle,[15] and may possibly be the contributing traumatic agent.

THE LESION

As in osteochondritis dissecans elsewhere, roentgenologic studies of the elbow

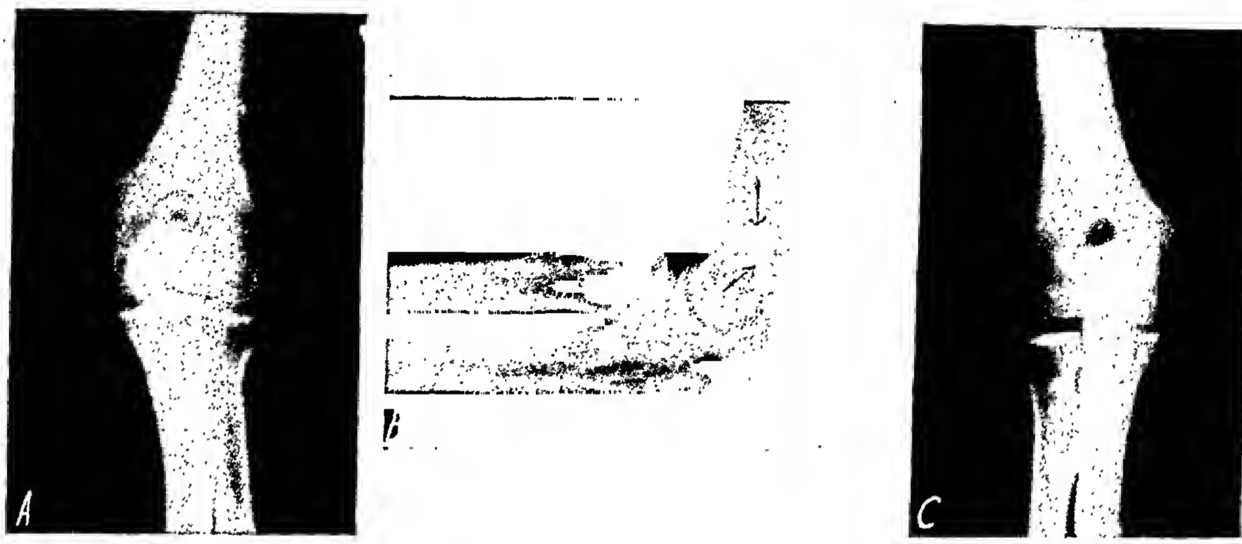

Fig. 1. Case 1. L. L., aged twenty-one. With no history of direct injury, the left elbow locked and was painful for four days. The pain recurred in three months and lasted two days. Examination revealed a 40° diminution of flexion and extension of left elbow.

Roentgenographic examination demonstrates (*A*) a single circular osseous nucleus situated in the supratrochlear septum of the left humerus. A clearly defined translucent zone borders the nucleus; this is the fibrous tissue replacement zone where separation occurs. In (*B*) the arrows indicate the undisplaced ossicle in the supratrochlear septum. The opposite elbow (*C*) demonstrates an extremely thin supratrochlear septum which occupies an identical site and is of similar contour to the defect on the left side. (Reproduced by permission from the *Journal of Bone and Joint Surgery*, January, 1945, 27, 12–24.)

supratrochlear foramen or an unusually thin septum in one arm and osteochondritis dissecans in the opposite one in 4 of our cases (Fig. 1*C*). Removal of the osteochondritic nucleus results in a defect of similar roentgenologic appearance to that of a supratrochlear foramen (Fig. 3*C* and 4*C*). This further suggests a common basic etiology.

Although the site would appear unusual, in that it is not a condylar surface, abutment of the olecranon process or the coronoid process of the ulna respectively in full extension or flexion is possible. Such may then be considered analogous to the situa- in the classical case discloses a circular button of bone lying in the olecranon or coronoid fossa intimately in contact with the lower and intra-articular portion of the supratrochlear septum (Fig. 1 and 2). The ossicle or nucleus has a somewhat more dense periphery which in turn is bordered by a translucent zone of varying thickness, depending on the degree of separation. Partial or completely free extrusion into the contiguous joint space may occur.

In some cases the nucleus may be fragmented, with several osteocartilaginous bodies of amorphous and granular appearance in the humero-ulnar joint (Fig. 3 and

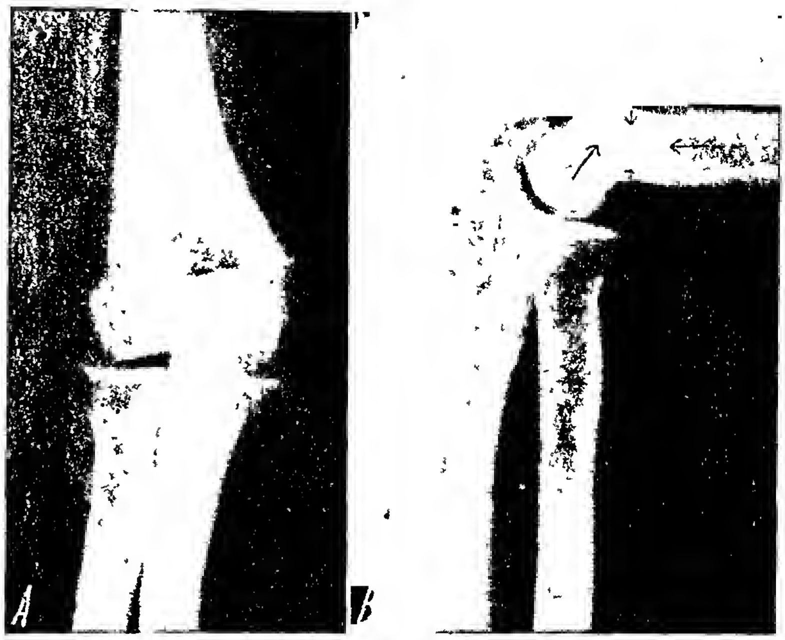

Fig. 2. Case II. R. J. W., aged thirty-two. Patient was a carpenter before joining the Navy. Onset of symptoms occurred fifteen years previously with sharp pain in the right elbow. Attacks occurred intermittently every two weeks to six months; the last occurred after playing baseball. Excessive hammering was stated to be responsible for similar attacks. Maximum tenderness was above olecranon process. Seventy per cent flexion and extension was present in right elbow.

Roentgenograms (*A*) and (*B*) illustrate an ossicle almost identical to that shown in Figure 1. Note the translucent zone centrally, the increased bony density at the periphery and the bordering translucent zone of separation.

The ossicle was removed at operation and subsequent roentgen examination disclosed a perforate septum formerly occupied by the removed fragment. A supratrochlear foramen was present in the opposite elbow. (Reproduced by permission from the *Journal of Bone and Joint Surgery*, January, 1945, *27*, 12–24.)

Fig. 3. Case III. E. P. M., aged twenty-four. This patient, a Chief Petty Officer, has been in the Royal Canadian Navy for seven years as a gunner. He was serving on two Canadian destroyers at the time of their sinkings. He recalls no elbow injury although he was admitted to a hospital in England with concussion and abrasions. The first attack of pain in the right elbow occurred five years ago, without aggravating circumstances. The second attack occurred one year ago and he was under medical observation for five months, when operation was performed.

Roentgenographic examination (*A*) illustrates an ossicle which has sequestrated from the supratrochlear septum and is situated in the coronoid fossa as shown in (*B*). In this instance the ossicle appears amorphous. It has apparently fragmented, as a second intra-articular ossicle is shown at the olecranon tip (*A*) and (*B*). This has possibly arisen from the upper portion of the main fragment where a local translucency is seen. (*C*) demonstrates what is now a supratrochlear foramen following removal of the large nucleus which was unattached. Note the marginal increase in density. This projection was taken in semi-extension to obviate superimposition of the olecranon tip and the septum. A supratrochlear foramen was present in the opposite side. (Reproduced by permission from the *Journal of Bone and Joint Surgery*, January, 1945, *27*, 12–24.)

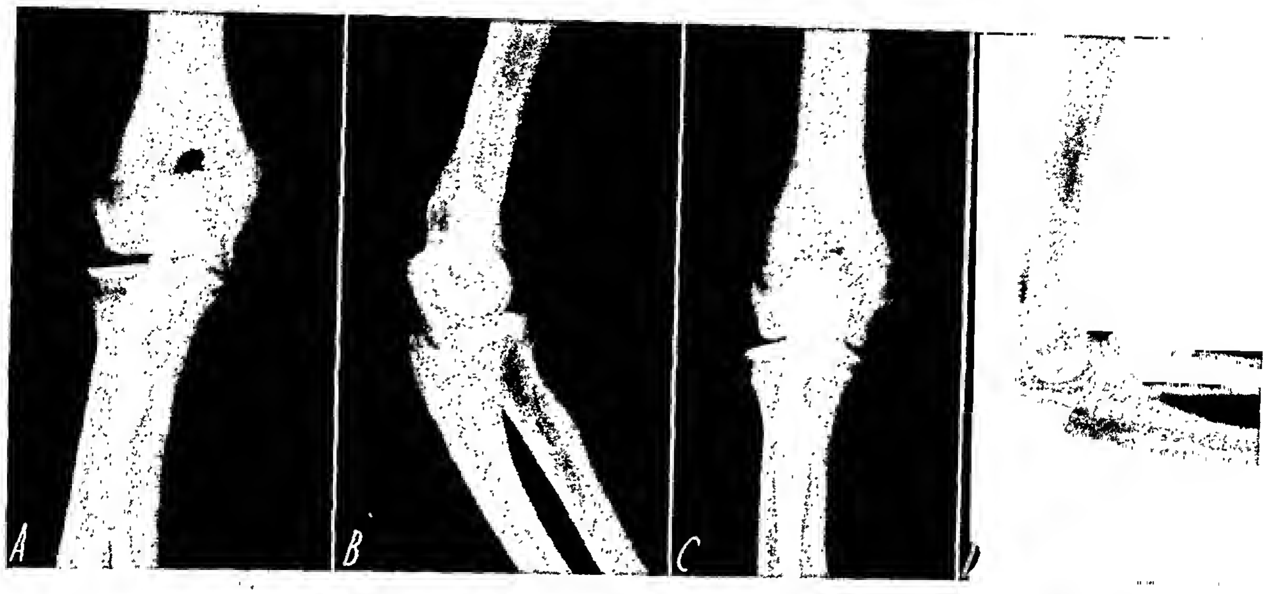

Fig. 4. Case iv. A. S. C., aged nineteen. Pain first occurred in February, 1943, following a softball game, and lasted for a week. There was limitation of movement and treatment was a sling for the elbow. In December, 1943, he had a sharp recurrence; at this time tenderness was present in the cubital fossa and flexion and extension were limited.

Roentgenographic examination (*A*) illustrates a septal perforation with an amorphous and faintly calcified nucleus centrally: (*B*) reveals this sequestrum to be situated in the coronoid fossa. (*C*) and (*D*) demonstrate the elbow after removal of the ossicle. Note an ossicle now present in the olecranon fossa. This is also seen in (*A*) overlying the capitellum and was erroneously interpreted as a bone island. (*A* and *B* reproduced by permission from the *Journal of Bone and Joint Surgery*, January, 1945, 27, 12–24.)

Fig. 5. Case v. T. K., aged thirty. Four years ago, injury occurred to left elbow with pain lasting one week. Two years ago, while throwing a dunnage bag weighing 100 lb., the left elbow locked.

Roentgenographic investigation discloses evidence of osteochondritis dissecans of both the supratrochlear septum and the capitellum. In (*A*) and (*B*) the calcified, amorphous, loose bodies are shown both in the coronoid fossa and above the head of the radius. Note the irregular contour of the capitellum and the small focus of diminished density at its lower condylar surface. (*C*) and (*D*) illustrate this elbow following removal of the ossicles. The septum is of irregular density and is now seen to be composed of multiple perforations and excavations. (*A* and *B* reproduced by permission from the *Journal of Bone and Joint Surgery*, January, 1945, 27, 12–24.)

4). Still in others, multiple small osteocartilaginous fragments are sequestrated; the supratrochlear septum in such cases has an irregular density suggesting multiple incomplete defects or excavations (Fig. 5).

Osteochondritis dissecans was also present in the capitellum of the same humerus in 1 case (Fig. 5).

Generally, the opposite elbow revealed either an unusually thin or a perforate supratrochlear septum (Fig. 1*C*).

Clinically, these lesions would appear to be dormant for the major period of their development. After a seemingly trivial injury, the patients have presented themselves with the complaint of pain and limitation of movement at the elbow. The clinical findings, reported in detail elsewhere,[12] suggest in certain cases a recent shift in the position of the ossicle. In these, symptoms slowly subside with conservative treatment. If there has been an extrusion of the sequestrum, locking may occur and symptoms will persist and may increase. Removal of the osteochondritic ossicle in 5 cases led to complete recovery without known recurrence of symptoms.

Histopathologic examination of the removed ossicles in 5 cases disclosed the presence of marginal fibrous tissue replacement of bone, which corresponds to the bordering zone of translucency seen in the roentgenogram. Both normal and dead bone is present which accounts for the varying roentgenographic density of the ossicle. Ill defined, swollen, and also normal cartilage is seen. Occasional foreign body giant cells are demonstrated, and there is evidence of increased vascularity. These findings are illustrated in Figures 6 and 7. This distribution and character are similar in pattern to that of osteochondritis dissecans found elsewhere.[2] There is no evidence of an infective etiology.

Fig. 6. Low power photomicrograph of the removed ossicle in Case II. This discloses a fibrous tissue border surrounding the ossicle. Swollen and ill defined cartilage cells are present at the left with normal and dead bone at the right. (Reproduced by permission from the *Journal of Bone and Joint Surgery*, January, 1945, *27*, 12–24.)

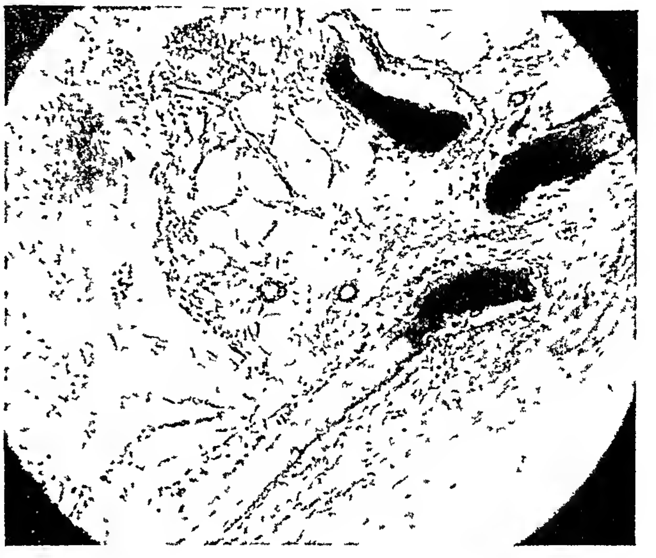

Fig. 7. High power photomicrograph of the removed nuclei from the supratrochlear septum of Case V. This illustrates the presence of a fibrous tissue bed at the left which has replaced the adjacent bone. Bone marrow fat cells are present centrally. Osteoclasts are at the periphery of the bony spicules shown at the right and here a few foreign body giant cells are present. Note the rather abundant arterioles and venules. (Reproduced by permission from the *Journal of Bone and Joint Surgery*, January, 1945, *27*, 12–24.)

SUMMARY

A localized lesion of the intra-articular portion of the supratrochlear septum of the humerus, previously confused with sesamum cubiti, has been shown to be an osteochondritis dissecans.

A supratrochlear foramen or thin septum in the opposite humerus is common and lends credence to the theory of vascular abnormality during growth as a predisposing cause. Local impingement of the coronoid or olecranon processes may be a contributory primary agent.

Symptoms may not exist or remain subclinical for a considerable time. The minimal traumata associated with the onset of clinically noticeable symptoms cannot be considered the major causative agent.

Extrusion of the nucleus as a loose body in the joint may occur.

Surgical removal affords complete relief of symptoms.

The authors wish to express their appreciation to Surgeon Commander C. B. Peirce, Consultant Radiologist, R.C.N., for his advice in the preparation of this paper; also to the late Dr. G. A. McCurdy, Director, Department of Pathology, Royal Jubilee Hospital, Victoria, B. C., and to Dr. C. Yuille, Department of Pathology, McGill University, Montreal, Quebec, for their assistance in the preparation and interpretation of the histopathologic findings.

REFERENCES

1. ATSATT, R. F. Loose bodies in the elbow joint: unusual location and form. *J. Bone & Joint Surg.*, 1933, *15*, 1008–1009.
2. BOYD, WILLIAM. Surgical Pathology, Fifth edition. W. B. Saunders Co., Philadelphia, 1942, p. 731.
3. BURMAN, M. S. Unusual locking of elbow joint by sesamum cubiti and a free joint body. AM. J. ROENTGENOL. & RAD. THERAPY, 1941, *45*, 731–732.
4. FRAZER, J. E. S. The Anatomy of the Human Skeleton. Third edition. J. & A. Churchill, London, 1933, p. 89, Fig. 63 and 68.
5. GRAUER, S. Ein atypischer Knochenschatten im Ellbogenbereich. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1927, *36*, 1277–1278.
6. HIRSH, I. S. Supratrochlear foramen; clinical and anthropological considerations. *Am. J. Surg.*, 1927, *2*, 500–505.
7. HABBE, J. E. Patella cubiti; report of four cases. AM. J. ROENTGENOL. & RAD. THERAPY, 1942, *48*, 513–526.
8. KLEINBERG, S. Osteochondromatosis of elbow. *Ann. Surg.*, 1934, *99*, 480–486.
9. KIENBÖCK, R. *Wien. klin. Wchnschr.*, 1903, p. 634.
10. KÖHLER, A. Röntgenology: The Borderlands of the Normal and Early Pathological in the Skiagram. Second edition. William Wood & Co., Baltimore, 1935, pp. 61–62.
11. *Ibid.* Pp. 67–68.
12. MORTON, H. S., and CRYSLER, W. E. Osteochondritis dissecans of the supratrochlear septum. *J. Bone & Joint Surg.*, January, 1945, *27*, 12–24.
13. O'DONOGHUE, D. H., and SELL, L. S. Persistent olecranon epiphyses in adults. *J. Bone & Joint Surg.*, 1942, *24*, 677–680.
14. PFITZNER, W. Beiträge zur Kenntnis des menschlichen Extremitätenskelets. Zweite Abt. IV. Die Sesambein des menschlichen Körpers. *Morphologische Arbeiten*, 1892, *1*, 517.
15. RICHARDS, G. E. Osteochondritis dissecans. AM. J. ROENTGENOL. & RAD. THERAPY, 1928, *19*, 278–284.
16. WINCKLER. Ein atypischer Knochenschatten im Ellbogenbereich. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1928, *37*, 502.

NEOPLASMS OBSERVED IN AN ARMY GENERAL HOSPITAL

REPORT OF THREE CASES: TWO CYSTS OF THE MEDIASTINUM AND A FIBROMA OF THE STOMACH*

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A GENERAL HOSPITAL is established by Army Regulations "to study, observe and treat the more obscure and more complicated cases." Therefore, in such a selected group of cases the number of neoplasms encountered is higher than might be anticipated in men of average Army age.

An analysis of the first 3,045 admissions to this hospital reveals that a diagnosis of neoplasm was made in 45 instances. Thirty of these men were admitted because of a tumor, while such a finding was incidental in the remaining 15 cases.

As indicated in the tables, 28 of the tumors were benign, while 17 were malignant. The location and type of tumor and, in the case of the malignant neoplasms, the age of the patient are shown.

It is to be noted in Table II that carcinoma of the lip and the lower large bowel occurred with much greater frequency in younger individuals than would normally be expected.

Because of their roentgenologic interest 3 of the more unusual benign tumors are here reported.

Two are cases of mediastinal tumors—a dermoid cyst and a teratoma. Roentgeno-

Table I

BENIGN NEOPLASMS 28

Location	Type	No.
Bone	Chondroma, enchondroma, etc.	4
	Bone cyst	1
	Osteoma	1
	Giant cell tumor	1
	Dentigerous cyst—mandible	1
Skin	Lipoma	7
	Fibroma	2
	Hemangioma	1
Rectum	Papilloma	1
Nose	Mixed tumor (cartilaginous)	1
Eye	Pigmented nevus	1
Thyroid	Adenoma	3
Mediastinum	Dermoid	1
	Teratoma	1
Stomach	Fibroma	1
Spinal cord	Xanthoma	1
	Average age 22 yr.	

Table II

MALIGNANT NEOPLASMS 17

Location	Type	Age yr.	No.
Bone	Chondromyxosarcoma (tibia)	20	1
	Anaplastic periosteal sarcoma (mandible)	20	1
Skin	Carcinoma	23, 23	2
Lip	Carcinoma	23, 25, 28, 29	4
Rectum and sigmoid	Adenocarcinoma	28, 29, 34, 45	4
Eye	Malignant melanoma	21	1
Brain	Malignant glioma	29, 34	2
Pancreas	Carcinoma	58	1
Testicle	Seminoma	28	1
		Average age 29	

* From the Hoff General Hospital, Santa Barbara, California.

Fig. 1. Case 1. Dermoid of mediastinum.

graphically, these tumors both present a more or less sharply circumscribed, often superior and predominantly anterior extra density in the chest (Fig. 1, 2, 4 and 5). According to Hammarskjöld[4] dermoids are more sharply outlined than teratomas. The mediastinal structures are often displaced by these tumors. Phemister, Steen and Volderauer[8] noted that a fluid level may be seen at times in dermoid cysts (Fig. 1 and 2). This is attributed to the layering of lighter oils present within the cysts. Roentgenoscopically, transmitted pulsation is seen. Where the tumor is firmly lodged between the bony thorax and the heart or great vessels, the pulsation may appear to be expansile.

The most frequent symptoms are chest pain, cough and dyspnea.[3] Hemoptysis sometimes occurs and the coughing up of hair is pathognomonic of mediastinal dermoid eroding a bronchus.[6] Adequate and complete surgical removal is indicated, for rupture of the tumor may lead to pneumonia or empyema.[5,9] Moreover, malignant degeneration is not uncommon.[3]

Case 1. *Dermoid cyst of mediastinum.* J.W.W., white, aged twenty, soldier of the Regular Army who had had one year and ten months of duty. He had been well and had had no chest symptoms. Five weeks before admission to this hospital he developed a severe earache on the right, accompanied by a high fever, headache and pain in the left chest. He was hospitalized near his station. The left chest was aspirated and a relatively large amount of fluid was removed. The nature of this was not learned. At that time numerous roentgenograms of the chest were taken and a "cyst-like formation" was found in the left chest anteriorly. Two attempts were made to aspirate the cyst. Two weeks after the onset of his illness swelling of the left leg was noted.

On admission to this hospital his pulse was 100 and his temperature was normal. The blood pressure in the right arm was 152/92, in the left 105/90. He appeared rather pale and underweight, and there was slight swelling of the left leg. In all other respects his general physical examination was essentially negative except for the chest where, in the second and third interspaces on the left, the retromanubrial dullness was increased. In this area the breath sounds were somewhat diminished. The labora-

Fig. 2. Case 1. Dermoid of mediastinum.

tory findings, including the blood count, urinalysis and serology, were not unusual.

Roentgenograms of the chest (Fig. 1 and 2) and roentgenoscopic examination revealed a sharply outlined, rounded shadow of approximately maximum cardiac density at the level of the second and third anterior interspaces to the left of the midline and above the left ventricular outline. It was seen to be anterior and, in its apex, there was a visible air or lighter fluid shadow (Fig. 2). This latter finding disappeared and could not be seen on later roentgenograms. During the following month the cyst did not increase in size.

His general condition improved and the thrombophlebitis of his left leg subsided, although this leg remained slightly larger than the right. One month after admission the tumor was removed by Captain Paul C. Samson through an anterior incision with removal of a segment of the third costal cartilage. Endotracheal anesthesia was used. The phrenic nerve was seen to pass through the wall of the tumor and was sacrificed. Postoperatively several aspirations were required to remove pleural fluid, but the chest rapidly cleared (Fig. 3). He was returned to duty symptom free.

Pathological Findings. The cyst was opened at surgery and was received in a collapsed state. Its contents were seen to be approximately 1 ounce of soft, brownish granular material having the consistency of cottage cheese and in which a few hairs floated. No structures were found which could be said to be teeth. The cyst, when reconstructed, measured about 6 cm. in diameter, and showed, on its external surface, many tags of fibrous tissue which were quite vascular. A small, encapsulated nodule measuring 5 mm. was found attached to the cyst wall externally and appeared to be a lymph node. On section it contained a necrotic, cheesy material. On the internal wall of the cyst there was a plaque of firm tissue measuring 3 cm. in diameter which grossly suggested cartilage. A white streak was buried in the adjacent cyst wall measuring 2.5 cm. in length and this was thought to represent a nerve fiber. Otherwise the cyst was uniformly thin, averaging about 1 mm. in thickness.

Microscopically the cyst wall was seen to be made up of fibrous tissue which was more or less laminated due to the pressure of the cyst contents. Marked pigment deposition was noted to suggest old hemorrhage, and scattered

Fig. 3. Case i. Dermoid of mediastinum at discharge from hospital.

areas of calcification were seen, particularly in the plaque described grossly. Cholesterol clefts and deposits were apparent. Attached to one wall was a considerable portion of lymphoid tissue which contained definite Hassall's corpuscles of thymus gland. No evidence of malignancy was seen. Diagnosis: Dermoid cyst of the mediastinum, benign.

Case ii. *Teratoma of mediastinum.* F.M., white, aged twenty-two, selectee, who had been in the Army but four months. He had been entirely well until one month before entering the Service when he first noted a fleeting sharp pain in the upper anterior chest when he held his left arm in certain positions. This did not concern him greatly. However, scon the pains became more frequent and more prolonged, gradually changing to a dull, persistent aching which was more severe when he was exposed to cold or wet weather. Change of position seemed to aggravate his discomfort. One month before admission he was seized by a sudden, severe chest pain and had considerable difficulty in getting his breath. The attack lasted for three or four hours and there were no recurrences. He was hospitalized at his camp for this, how-

Fig. 4. Case 11. Teratoma of mediastinum.

ever, and a gradually increasing cough productive of small amounts of yellowish sputum appeared which aggravated his pain and caused some dyspnea. About two weeks before his transfer to this hospital a tonsillectomy was performed.

At the time of his admission he complained of the cough, chest pain and dyspnea on exertion. He had noted no dysphagia, and a general review of his symptoms revealed no other abnormalities. His temperature was normal and his general physical examination was essentially negative except for the chest where there was some increase in the retromanubrial dullness in the third and fourth interspaces to the left. The blood pressure in the right arm was 130/75 and in the left, 138/72. A slight leukocytosis was attributed to his recent tonsillectomy.

Roentgenograms of the chest (Fig. 4 and 5) and roentgenoscopic examination revealed a large tumor mass which extended from the hilum anteriorly and laterally on the left and which displaced the heart and mediastinal contents downward and to the right. It was sharply outlined by normal air containing lung except on its extreme lateral margin where a zone of increased density suggested compression of the adjacent tissues. It measured approximately 10 cm. in each of its greater diameters. In the lateral projection it was seen to be firmly placed between the anterior chest wall and the heart and great vessels. Expansile type pulsation was marked.

One month after admission the tumor was removed under endotracheal anesthesia by Captain Paul C. Samson. The third and fourth cartilages on the left were removed and a rounded, semisolid mass was shelled out. The phrenic nerve was dissected free from the posterior wall of the cyst. Postoperatively, he rapidly regained his strength, and was up on the tenth day, and at the time of return to duty (Fig. 6) showed only moderate fibrosis at the former site of the tumor.

Pathological Findings. A rounded cystic mass was received which measured approximately 10 cm. in two directions and 12 cm. in its longest diameter. Its external surface was smooth yellow blending into pink and white. On one portion of the surface vascular fibrous tissue could be seen. The contour of the wall was broken by projections or nodules, six or so in number, which varied in size from 1 to 4 cm. and had an average elevation of 1.5 cm. The entire mass was tense and cystic. On its cut

Fig. 5. Case 11. Teratoma of mediastinum.

surface, when bisected, a large group of fatty lobules occupied one area. They were separated by septa of dense white tissue which appeared fibrous in some areas and cartilaginous in others. Other zones contained numerous cystic cavities varying in size from 1 mm. to 1.5 cm., some of which contained a clear, thick, mucoid material. A few of these suggested ducts and several were apparently lined by mucosa. Where the cartilage was densest, the cut surface revealed a dark red central portion suggesting bone marrow. Other cystic spaces contained sebaceous material and hair. Gland tissue was identified in one portion. In general, the tumor was not very vascular.

Microscopically, the large yellow lobules noted grossly were fat tissue, and the dense white septa were fibrous tissue with many small hemorrhages throughout. One section revealed thymic tissue represented by Hassall's corpuscles in lymphoid tissue. Other sections from the inner portion of the tumor showed the cystic and duct-like areas to be lined by various types of epithelium or only by a rather dense, laminated fibrous tissue. Hyalin cartilage formation was apparent lying in a lobule of fat tissue, and bundles of smooth muscle fibers were seen which appeared somewhat interlaced as in the myocardium. One cyst was lined by a stratified or pseudostratified columnar epithelium suggesting respiratory tract lining. Other areas were seen, lying within the fibrous tissue, which were lace-like and composed of thin strands of tissue in which there were scattered and isolated nuclei. These nuclei had rather distinct nucleoli but poorly outlined cytoplasmic envelopes. This particular tissue resembled white matter of the central nervous system. Mixed type, mucus secreting glands were found, and skin with stratified squamous epithelium and sebaceous glands was identified. The lining of several spaces was that of small intestine, while in others large intestinal mucosa was described. The structure grossly thought to resemble gland tissue proved to be a fairly large, lobulated gland in which ducts could be seen. It had the appearance of pancreas. Bone was present with trabeculae, around and between which connective tissue and large blood sinuses were found. There was a large cellular collection but no definite evidence of hematopoiesis. Diagnosis: Mediastinal teratoma, benign.

The third benign tumor was a fibroma

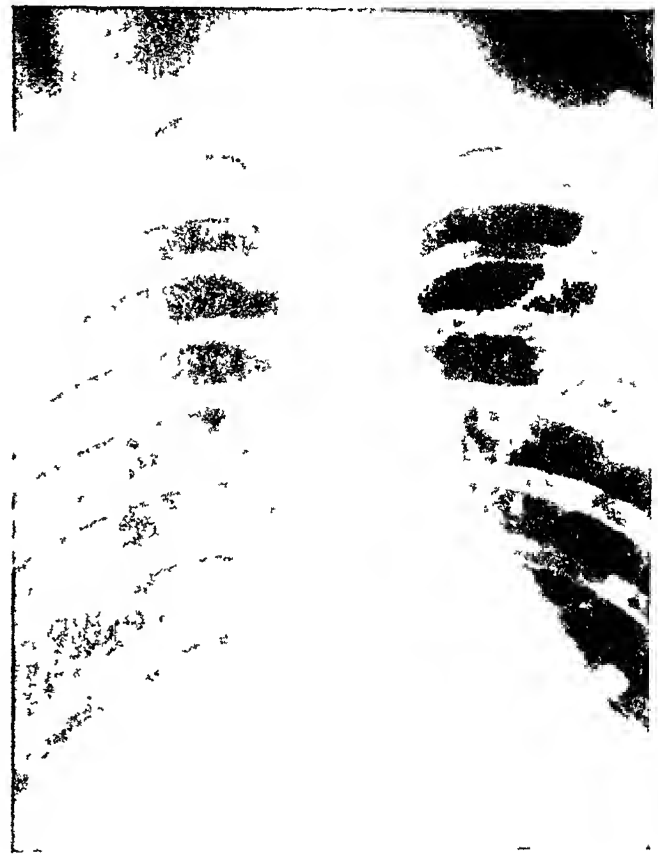

Fig. 6. Case II. Teratoma of mediastinum at discharge from hospital.

of the stomach. Benign gastric neoplasms are rare, representing less than 0.5 per cent of all gastric tumors at the Mayo Clinic.[1] In a series of 931 such tumors collected from the literature by Minnes and Geschickter[7] there were but 42 fibromas, representing about 4.5 per cent. Roentgenographically, benign tumors of the stomach are characterized by absence of infiltration of the stomach wall and by the uninterrupted flow of peristalsis over the tumor.[2] In the case here presented the mass was so large that neither of these phenomena could be observed. A smooth outline of the tumor is suggestive of benignity. The potential malignancy of a gastric fibroma is unknown, but spindle cell sarcoma, a rare entity indeed, has been reported.[1] Mechanical obstruction as in the following case is frequently the cause of the symptoms.

Case III. *Fibroma of the stomach.* A.L., white, aged twenty-five, selectee, who had been in the Army for five months. He had had no symptoms or complaints relative to his stomach until six weeks before admission. At that time there was

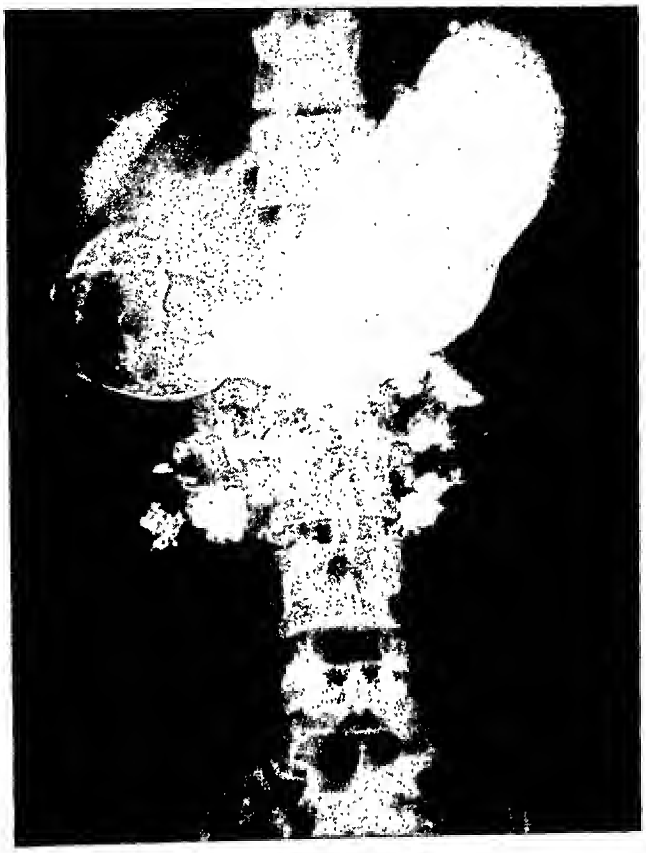

Fig. 7. Case III. Fibroma of stomach.

a gradual onset of abdominal pain, mid-epigastric in location and cramping in type. His appetite was then good and he obtained relief from his symptoms by vomiting. However, the pain gradually increased as did the vomiting and soon he lost all desire for food. There was no hematemesis. No tarry stools were noted but the patient was constipated. There was no history of jaundice.

On admission to the Hoff General Hospital he was found to be a fairly well nourished young man who had obviously lost some weight. His general physical examination, including pulse, temperature and respirations, was essentially negative. The only positive finding was a palpable mass in the right upper quadrant just below the costal margin which was only to be felt when the patient was standing. There was a leukopenia of 2,500 and a very slight anemia.

The roentgen examination of the stomach showed considerable fluid and food retention although the patient had not eaten for over twelve hours. The stomach was dilated but had surprisingly good tone and showed ineffectual peristalsis. In the distal third the barium was displaced by a large mass which extended beyond the usual position of the pylorus and which obscured the upper portions of the duodenum (Fig. 7). It was roughly egg shaped and measured 6 by 8 cm. It seemed to lie anteriorly and barium could be discerned on all of its borders, indicating that it was within the lumen of the stomach. It could not be moved within the stomach.

A gastroscopy was done but the pylorus could not be visualized and therefore some doubt was expressed as to how much of the antrum had been viewed. The proximal two-thirds of the stomach was considered to be essentially normal.

Two weeks after admission the abdomen was opened by Major Walter Birnbaum through an upper abdominal incision. When the stomach was opened the tumor was seen to arise from the posterior gastric wall in the immediate region of the pylorus. The distal third of the stomach was resected and a Billroth gastroduodenostomy was done. The patient was convalescing satisfactorily at the time of this report.

Pathological Findings. The specimen was the distal third of the stomach which had been opened along the lesser curvature (Fig. 8). Attached to the posterior wall and projecting into the lumen was a firm, rubbery and fairly smooth tumor mass which measured 9 by 5 by 5 cm. The area of attachment measured about 5

Fig. 8. Case III. Fibroma of stomach, operative specimen.

cm. About this pedicle, tumor tissue was palpated in the stomach wall. It was more nodular than the intraluminal portion. The area of mural involvement measured 7 by 5.5 by 5 cm. and represented slightly less than two-thirds of the total mass. The mucosa of the surrounding stomach wall appeared intact, while the tumor covering appeared to lack epithelium. No tumor was found on the serosal surface and a complete capsule was thought to be present. There was slight thickening 2 cm. from the distal end which was thought to represent the pylorus, now totally distorted.

On section the tumor cut with some resistance and grating, and the surface thus revealed appeared not unlike a uterine fibroid. There were whorls of white fibrous tisue with a central portion of increased translucency which exuded a clear fluid and suggested degenerative change. No cystic changes were noted.

Microscopically, the tumor was separated from the serosa by a fairly definite layer of stomach wall. The mucosa of the stomach was quite normal in appearance but did not extend over the intraluminal portion of the tumor which was covered by a thin capsule of flattened fibrous tissue cells. The tumor itself was composed of strands of collagenous tissue which in some places were in parallel bundles, and in others quite irregular in arrangement. It was relatively cellular, with fairly uniform nuclei. A few blood vessels were seen throughout the tumor which were normal in appearance. Van Gieson's stain showed the tissue to be fibrous, no muscle being demonstrated except in the vessel walls. In the soft central portion myxomatous degeneration was found, with the fibroblasts assuming spindle and stellate shapes. There were no mitotic figures and no evidence was found of extension into the lymphatics or vessels. A section of the distal portion of the stomach revealed large Brunner's glands in the submucosa, indicating that the excision included the pyloric ring and a small portion of the duodenum.

Diagnosis: Benign fibroma of the stomach with myxomatous degeneration in its central portion.

SUMMARY

Forty-five tumors encountered in 3,045 admissions to Hoff General Hospital have been listed. Three cases of unusual interest have been discussed in detail.

REFERENCES

1. Boyd, William. Surgical Pathology. Third edition. W. B. Saunders Co., Philadelphia, 1933.
2. Golden, R., Editor. Diagnostic Roentgenology, Thomas Nelson & Sons, New York, 1941.
3. Haagensen, C. D. Differential diagnosis of primary neoplasms of mediastinum. *Am. J. Cancer*, 1932, *16*, 723–782.
4. Hammarskjöld, B. Contribution of knowledge of teratomas and dermoids in anterior mediastinum. *Acta radiol.*, 1934, *15*, 210–224.
5. Heuer, G. J. Surgery of mediastinal dermoids. *Ann. Surg.*, 1929, *90*, 692–713.
6. Kerr, H. H., and Warfield, J. O., Jr. Intrathoracic dermoids. *Ann. Surg.*, 1928, *88*, 607–629.
7. Minnes, J. F., and Geschickter, C. F. Benign tumors of stomach. *Am. J. Cancer*, 1936, *28*, 136–149.
8. Phemister, D. B., Steen, W. B., and Volderauer, J. C. Roentgenologic criterion of dermoid cyst. Am. J. Roentgenol. & Rad. Therapy, 1936, *36*, 14–18.
9. Robertson, C., and Bevan Brown, R. E. Dermoid cyst of mediastinum. *Brit. J. Surg.*, 1929, *17*, 197–202.

INTERSTITIAL EMPHYSEMA AND PULMONARY COLLAPSE COMPLICATING FRACTURES OF THE SKULL

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THE purpose of the present examination is to call attention to the fact that fractures of the skull may be associated with interstitial emphysema and pulmonary collapse.

CASE REPORT

C.K. (No. C-475), a Chinese male, aged twenty-five, was admitted to the Neurosurgical Section of an overseas general hospital in an unconscious state at 0540 hours on May 1, 1943. The patient had been shot through the head about two hours earlier.

Examination. The patient was a short, well developed individual. He was unconscious and reacted feebly to painful stimuli. Respirations were stertorous, forced, and rapid (40 per minute). With each expiration foamy mucus was blown out of the mouth. The pulse rate was about 180. The head was covered with coagulated, dried blood. Palpation of the skull revealed diffuse subgaleal bleeding. Crepitus could be elicited by gentle pressure over the left frontal bone. A scalp wound about one-half inch in diameter was easily identified in the left parietal region. Examination of the remaining portions of the body revealed no gross abnormalities. The patient was in severe shock.

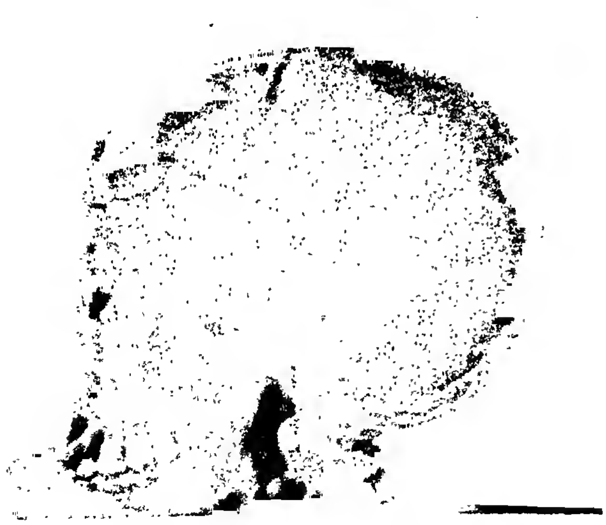

FIG. 1. Lateral roentgenogram of the skull revealing the bone defect produced by the bullet. The multiple lines of fracture are well visualized.

Neurological examination showed the pupils to be equal and of moderate size. They did not react to light. The right arm and, to a lesser degree, the right leg were spastic. The left arm and leg moved slightly when stimulated. No reflexes could be elicited.

The response to treatment was unsatisfactory. The patient remained in shock in spite of the intravenous administration of plasma and other fluids. Respiration became more difficult and forced. All the accessory respiratory muscles seemed to be brought into action with each inspiration. The respiratory rate gradually increased to 64. The foamy mucus blown from the mouth with each expiratory effort became more abundant and bloody. Frequent oral aspiration by means of a soft rubber catheter failed to control the discharge.

At 1000 hours, interstitial emphysema of the neck and upper chest wall was first noted. An adequate physical examination of the lungs was impossible because of the noisy respiration. The patient died at 1130 hours, five hours after admission to the hospital, and seven hours following his injury. A necropsy could not be obtained.

Roentgen Examination (completed within a few minutes after death). Head: Numerous fracture lines extending throughout the bones of the calvaria. The wound of entry is marked by a circular bone defect low in the right parietal region (Fig. 1). From this bullet hole at least five fracture lines extend in stellate fashion into the parieto-occipital, parietofrontal, and parietotemporal regions. The bone defect in the wound of exit is much larger and is located at a higher level in the right parietal region. Fragmentation of bone in this area is excessive. The fracture lines are wide and there is considerable separation of the fragments. Small spicules of bone and bubbles of air are

evident within the brain substance. Examination of the base of the skull reveals clouding of the entire left temporal bone. Fracture lines extending through the region of the tip of the left petrous pyramid and the clivus are easily identified. Neck: The lateral examination of the neck reveals interstitial emphysema involving the soft tissues behind the oro- and nasopharynx extending down into the posterior mediastinum (Fig. 2). Interstitial air is also identified in the soft tissues of the neck in the anteroposterior projection. Chest: The soft tissues of the chest reveal interstitial emphysema (Fig. 3). These changes are part of the process involving the neck and extend into both shoulders and down into the upper portion of the chest wall. The bones of the thoracic cage are negative. The trachea is in the midline. The mediastinal structures are outlined by interstitial air. The lungs are clear, though hypoventilated due to death. There is about 25 per cent collapse of the left lung. The domes of the diaphragm appear normal.

Direct examination of the nasopharynx by a competent observer revealed swelling of the mucous membrane, interstitial hemorrhage, and blood and mucus in the roof of this cavity.

Fig. 2. Lateral roentgenogram of the soft tissues of the neck and nasopharynx. The interstitial emphysema extending from the region of the clivus down the neck and into the superior mediastinum is clearly demonstrated.

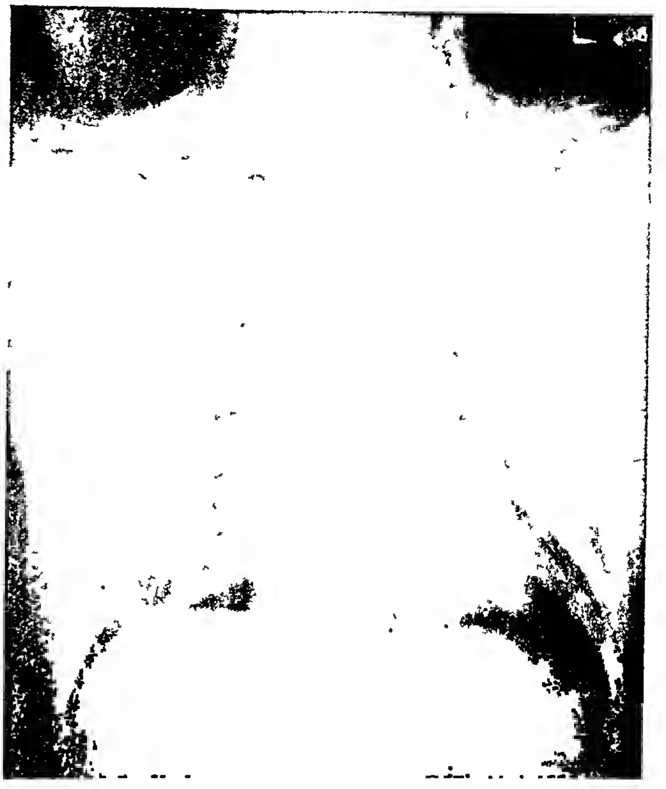

Fig. 3. Anteroposterior roentgenogram of the chest made immediately after death. The interstitial emphysema in the neck and lateral chest wall is easily visualized. Note the air surrounding the large blood vessels at the base of the heart. The left lung is partially collapsed.

COMMENT

Nothing is known concerning the nature of this patient's accident. He was brought into the hospital unconscious, failed to rally, and died five hours after admission. The noteworthy physical findings were the cranial injury, profound shock, and rapid stertorous breathing. Roentgen examination revealed multiple skull fractures which were associated with interstitial emphysema of the neck and chest.

DISCUSSION

Unfortunately, it was impossible to obtain permission for a postmortem examination of this patient. This presentation must therefore be considered incomplete. Nevertheless, the presence of interstitial emphysema and partial pulmonary collapse as complicating factors in a patient with a gun shot injury of the head and multiple fractures of the skull seem worth recording. Air within the skull (pneumocephalus)

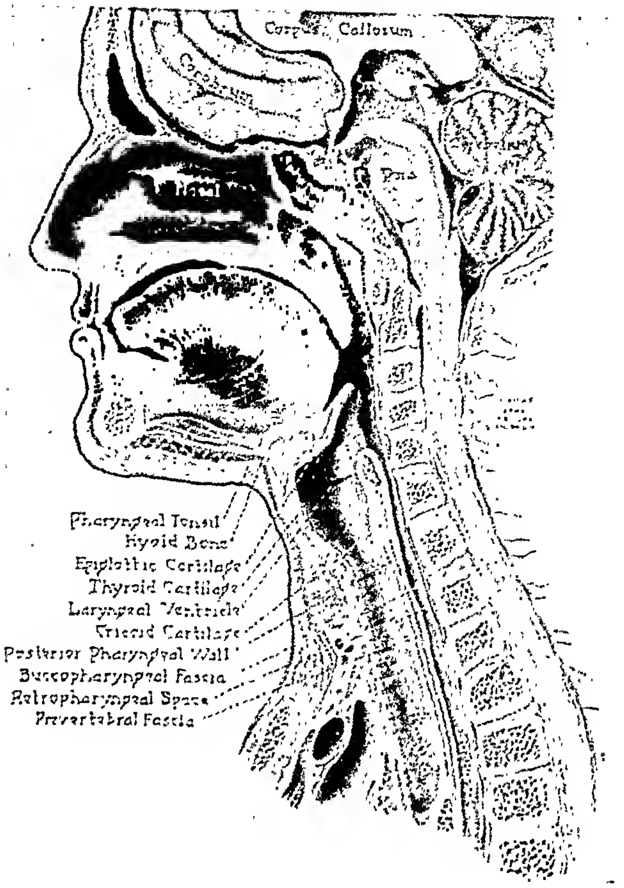

Fig. 4. Anatomic demonstration of the prevertebral fascial planes. Note the manner in which these fascial planes extend from the nasopharynx downward into the posterior mediastinum.

complicating skull injuries, has been frequently described. The presence of abnormal air in the soft tissues of the chest as a complication of skull fractures is unusual in our experience.

In our opinion, the fractures in the base of the skull were responsible for the interstitial emphysema. These fractures, which extended through the left petrous pyramid and the basilar portion of the occipital bone, were easily demonstrated roentgenographically.

In addition, direct examination of the nasopharynx by a competent observer revealed marked swelling of the mucous membrane, interstitial hemorrhage, and blood and mucus in the roof of this cavity. Whereas, a tear in the membrane lining the nasopharynx was not actually demonstrated, it seemed reasonable to attribute the nasoscopic findings to the basilar fractures which were probably compound. A tear in this portion of the nasopharynx could open fascial planes along which interstitial air could travel and enter the mediastinum.

According to Gray, the nasopharynx is limited above by the body of the sphenoid and basilar part of the occipital bone and is connected posteriorly by loose areolar tissue with the prevertebral fascia. The prevertebral fascia, which assists in forming the sheath of the carotid vessels, gives off the buccopharyngeal fascia which helps to form the retropharyngeal space. This easily distended space is limited above by the base of the skull while below it extends behind the esophagus into the posterior mediastinal cavity of the thorax. We believe the interstitial air demonstrated in our patient traveled along these routes (Fig. 4).

Clinically, the patient presented marked respiratory embarrassment. For at least five hours prior to death, his respirations were characterized by explosive expiratory grunts probably due to the swelling of the tissue of the nasopharynx and the oral mucus which interfered with breathing. We believe that this resistance to the normal respiratory cycle forced air into the loose areolar tissue surrounding the nasopharynx during each expiration. Once initiated, this vicious cycle continued until interstitial air found its way into the posterior mediastinum. Whether the partial pulmonary collapse was due to a pleural tear which allowed the air in the posterior mediastinum to enter the pleural cavity or whether the air, under pressure, stripped the parietal pleura from the chest wall (extrapleural pneumolysis) is a debatable problem. The evidence favors the latter hypothesis.

VISUALIZATION OF THE CORONARY ARTERIES IN DOGS*

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IN 1938 Robb and Steinberg introduced 70 per cent diodrast as a radiopaque contrast medium to visualize the chambers of the heart and its great vessels. Since then, roentgenographic examination of almost all the arteries and veins has become a routine matter at many institutions. To our knowledge, no method of demonstrating the coronary arteries in the living animal has been brought forth. In 1942 Barclay and his co-workers injected thorotrast retrogradely through the aorta to demonstrate the ductus arteriosus in sheep fetuses. As an incidental finding they pointed out that one of the coronary arteries was seen. This observation prompted the present work. We wish to elaborate this point to show that it is feasible to instill substances directly into the coronary circulation without opening the thoracic cage.

METHOD

Dogs were anesthetized with sodium pentobarbital (25 mg. per kilogram body weight given intravenously). A small incision was made in the mid-neck paratracheally on the right. The right common carotid artery was exposed and freed. The artery was ligated distally and a loose ligature was placed proximally. A bulldog clamp was fixed at the proximal end of the artery after the blood had been milked from the arterial segment between the ligature and the clamp. An incision was made in this arterial segment large enough to admight a No. 10 wax ureteral catheter (the tip of which had previously been bent to an angle of 35° and to the other end of which was affixed a piece of rubber tubing which was clamped to prevent the flow of blood during the insertion). The proximal ligature was tied snugly around the catheter to prevent leakage of blood around the catheter. The proximal clamp was removed from the artery and a small amount of 70 per cent diodrast was injected into the catheter to render it radiopaque. Under roentgenoscopic guidance, the catheter was insinuated until its tip reached the aortic arch. The catheter was then rotated on its longitudinal axis so that the tip pointed ventrally and was then inserted so that the tip was at the level of the most proximal portion of the aorta. This position was tested by injecting about 5 cc. of diodrast and observing its flow roentgenoscopically. If the catheter was properly in place the diodrast momentarily outlined the proximal aorta stopping abruptly at the aortic valves. If the catheter was not in good position the diodrast did not enter the intracardiac portion of the aorta and could be seen coursing along the transverse and descending aorta. In such cases withdrawal and manipulation resulted in good placement. A survey roentgenogram of the heart was taken in the left lateral recumbent position with the catheter in situ. The factors used were: 30 inch tube distance; 100 ma.; 80 kv. (peak) and 1/10 second exposure. The tube was centered just below the shoulder joint. Another roentgenogram was then taken in the same position during forceful injection of approximately 25 cc. of 70 per cent diodrast.

RESULTS

Twelve dogs were used. Of these, 7 were needed for the preliminary studies and the remaining 5 to show the consistency of the technique. The last five injections demonstrated the coronary arteries in each case,

* From the Cardiovascular Department and Department of Roentgenology, Michael Reese Hospital, Chicago. Aided by the Emil and Fanny Wedeles Fund for Cardiovascular Research. The Cardiovascular Department is supported in part by the Michael Reese Research Foundation.

[illegible]

[illegible] aorta, brachiocephalic [illegible] internal mammary arteries [illegible] the left ventricle. In [illegible] demonstrating [illegible] phases of [illegible] death.

[illegible]

1. A method [illegible]

[illegible]

2. The coronary arteries can be visualized in the intact living animal by means of the instillation of 70 per cent diodrast.

We are indebted to Winthrop and Co. for supplying the 70 per cent diodrast. I wish to acknowledge the assistance given by Dr. B. Kondo and Miss L. Friedberg, and the guidance of Dr. L. N. Katz.

REFERENCES

1. Robb, G. P., and Steinberg, I. Practical method of visualization of the chambers of the heart, the pulmonary circulation, and the great blood vessels in man. *J. Clin. Investigation*, 1938, *17*, 507.
2. Robb, G. P., and Steinberg, I. Visualization of chambers of the heart, pulmonary circulation, and great blood vessels in man; practical method. Am. J. Roentgenol. & Rad. Therapy, 1939, *41*, 1–17.
3. Robb, G. P., and Steinberg, I. Visualization of chambers of the heart, pulmonary circulation, and great blood vessels in heart disease; preliminary observations. Am. J. Roentgenol. & Rad. Therapy, 1939, *42*, 14–37.
4. Barclay, A. E., Barcroft, J., Barron, D. H., and Franklin, K. J. Radiographic demonstration of circulation through the heart in adult and in foetus, and identification of ductus arteriosus. Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 678–690.

IRRADIATION FAILURES IN EARLY CERVICAL CANCER

IMPROVED IRRADIATION OR RETURN TO SURGERY?*

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IT IS now generally accepted that *statistically* the results of adequate radiation therapy are superior to those of the radical Wertheim hysterectomy in the treatment of epidermoid carcinoma of the cervix in all stages. Before this audience I do not have to repeat the statistical evidence that has led to these conclusions.[3]

It is sufficient as a basis for this discussion to recall Regaud's classical comparison

TABLE I

COMPARATIVE RESULTS OF SURGICAL TREATMENT (FAURE) AND RADIATION TREATMENT (INSTITUT DU RADIUM) OF CARCINOMA OF THE CERVIX UTERI

Five year cures with radiation therapy (Institut du Radium, Paris, Regaud) 1922–1926	Number	Cures	Cures Per cent	Primary Mortality Per cent
Total Stage I–IV	380	124	32	2
Stage I	29	23	79	
Stage II	121	50	41	
Stage III	179	50	27	
Stage IV	51	1	2	
Five year cures with radical operations (Hop. Brocat, Paris, Faure)				
Total Stage I–II	90	30	33	19
Stage I	54	22	40	7
Stage II	36	8	22	36

between his irradiation results and the surgical results of Jean Louis Faure[10] (Table I).

The statistical results reported from the leading radiological clinics throughout the world are remarkably uniform in spite of differences in technique, provided the procedure is adequate. Some surgical results are better than those represented in this table. In optimal cases (probably early Stage I) about an 80 per cent five year cure rate with 6.5 per cent primary mortality was accomplished, while in borderline operable cases (probably Stage II to III) only 25 per cent could be salvaged, with a primary mortality of 30 per cent.[4] Without going into further details of this old discussion, I only want to point out that adequate radiation therapy yields at least results equal to excellent surgery, if the problem is viewed from a statistical point of view. In those instances in which surgeons have become disappointed with irradiation results and believe that they show a statistical superiority in their accomplishments over those of the radiation therapists, a critical analysis (if such is possible from the reported data) shows that irradiation results are not up to par; this means the cure rates are lower than those which have been attained by the leading radiological institutions which must be considered as the standards for comparison.

It is interesting to note from two studies by Lacassagne[5,6] the importance of adequacy of treatment as expressed in five year cures (Tables II and III).

But even if statistically the superiority or at least equality of radiation therapy for the operable Stages I and II—to our knowledge—so far has not been disproved by any critical analysis on record, the fact remains that now, as fifteen years ago, 20 per cent of Stage I and at least 30 per cent of Stage II cases are not cured by even the most competent and skillful radiation therapists. The

* Presented at the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, Chicago, Ill., Sept. 24–29, 1944.

question naturally arises whether these cases represent types of the disease essentially not suitable for radiation therapy (either because of the biological type of the tumor or because of the anatomical location of the spread) and if so, whether possibly some of these lesions could be controlled by radical hysterectomy provided they are recognized prior to treatment—or whether other reasons for these failures can be found which are not evident in a merely statistical evaluation. Taussig's[11] recommendation of an iliac lymphadenectomy in conjunction with irradiation, and Meigs'[7,8] recent resumption of the Wertheim operation for selected cases have again stimulated interest in this problem. It seems that this question cannot be solved by a statistical analysis only but that a careful analysis of the individual unsuccessfully treated cases must complement the statistical data.

Table II

CURE RATE IN RELATION TO QUALITY OF TREATMENT (LACASSAGNE, 1929)

Stage	Total Number	Incorrect Treatment Number	Cure Rate All Cases	Cure Rate in Correctly Treated Cases
I	10*	0	7: 9=78%	7: 9=78%
II	20	9	9:30=45%	8:11=72%
III	50	17	25:50=50%	20:33=60%
IV	15	14	1:15= 6%	1: 2=50%

* 1 died of intercurrent disease.

In 1940, for the clarification of our own opinion, we, together with John Wirth, analyzed the failures in cases treated at the Swedish Hospital Tumor Institute between 1935 and 1938.[14] Prompted by the challenge from such an authoritative surgical source as Meigs we have again reviewed the failures in the operable Stages I and II cases treated between 1935 and 1943.

Nineteen cases out of a total of 79 patients Stage I or II are dead at the time of this report or show active disease. The reasons for the failure in these instances are seen in Table V.

Table III

IMPROVEMENT IN CURE RATE WITH INCREASING EXPERIENCE (LACASSAGNE, 1932)

	Stage I	Stage II	Stage III
1919–1922	33%	26%	8%
1923–1926	86%	42%	30%

What can we learn from this analysis with regard to the two questions that prompted this investigation?

1. How many, if any, of these patients could have been saved by more adequate radiation therapy?

Three patients with controlled carcinoma died of complications secondary to an intestinal irradiation necrosis, one of them combined with a necrosis of the bladder. Two of these patients of slight build (95 and 105 pounds in weight) received a depth dose through large fields which was sufficient to cause lethal intestinal damage. Furthermore the radon therapy was given during the course of roentgen therapy which we know aggravates the intestinal injury. These patients were treated at a time when the dangers of supervoltage

Table IV

FAILURES OF RADIATION THERAPY IN OPERABLE STAGES I AND II TREATED BETWEEN 1935 AND 1943

	Stage I	Symptom Free	Stage II	Symptom Free
1935	1	1	3	2
1936	1	0	2	2
1937	1	0	7	2
1938	2	2	3	2
1939	4	3	2	2
1940	5	4	2	2
1941	4	4	4	3
1942	2	2	15	10
1943	5	4	16	15
Total	25	20	54	40
Failures	5		14	

roentgen therapy were not yet sufficiently understood and appreciated. We have since then learned to avoid such dangerous reactions by more individually adjusting the field size and dose to the size of the patient, by a more adequate timing of the radium application in relation to the course of roentgen therapy and by using radium element instead of radon, permitting a more prolonged treatment with uniform dosage rate. As can be seen from Table v no such injuries have occurred in the second observation series since these changes, based on the previous experience, have been introduced. It is obviously this kind of avoidable intestinal injury that Meigs observed in 46 cases which caused his statement that "there will be less damage to the bowel if surgery is undertaken." *It must be clearly understood that in later stages of the disease more severe intestinal reactions sometimes cannot be avoided if a permanent cure of the cancer is attempted. But for the early stages here under discussion severe intestinal reactions must today be considered as due to faulty treatment.*

Of the 4 patients with pelvic complications (Group 4, Table v) we believe that the one who died of a sepsis could possibly have been saved by a more judicious conduct of therapy. This was a Stage II carcinoma treated immediately post partum with an associated pelvic cellulitis before treatment was begun. The infection improved under external roentgen therapy but the intracervical radium therapy was given too soon, assuming the infection was controlled. In spite of all efforts the patient died of pelvic peritonitis.

Whether the patient who developed a pyometria following treatment and died of a pelvic abscess in spite of repeated drainage could be saved today is open to discussion.

The 2 other patients in this group were treated we believe as well as was possible and death was probably unavoidable.

The 2 patients in the sixth group we think might possibly have been saved by a better distribution of the dose in space.

Table V

ANALYSIS OF FAILURES

	1935–1938	1939–1943	1935–1943
1. Treatment incomplete	1 insanity	1 mental attitude	2
2. Distant metastases	1 pulmonary		1
3. Extrapelvic complications; pelvic disease controlled	1 cardiac	1 nephritis 1 meningitis p. otitis	3
4. Pelvic complication	1 pyometria 1 cancer with post partum sepsis	1 pregnancy 1 second pelvic care	4
5. Death from sequelae of treatment; disease controlled	2 intestinal obstruction 1 rectal and vaginal necrosis		3
6. Treatment errors, disease uncontrolled		2 low external dose	2
7. Unexplained	1	3	4

Case 1. G. O., aged thirty. June, 1942. Weight 134 lb. Anteroposterior pelvic diameter 23 cm., circumference 91 cm. Intermenstrual

bleeding for three months. Two weeks ago severe hemorrhage. Enlarged cervix with tumor breaking through anterior lip. Endocervical carcinoma, Stage II. Considerable infection. Microscopic examination showed a very anaplastic squamous carcinoma.

External roentgen irradiation, 9,700 r in thirty-three treatment days, 800 kv.; vaginal roentgen irradiation (after initial external roentgen irradiation of 2,600 r for infection), 7,465 r in twelve days. Radium treatment, 4,040 mg-hr. (2,020 mg-hr. cervical tandem, 2,020 mg-hr. vaginal ovoids). External roentgen treatment given through one anterior medial 10 by 14 cm. field (3,350 r), one sacral medial field (1,200 r) and one right and left sacroiliac field. No anterolateral suprapubic fields were used and therefore the parametrial dose was insufficient while the central dose was too high, considering the intravaginal application. Repeated loose bowel movements throughout treatment, probably due to the initial central dose of 2,600 r in eight days, given because of the infection. On account of this irritation, the total external roentgen dose was too low.

September, 1942, two normal bowel movements daily. Cervix normal on palpation, injected; rectovaginal septum soft. October, 1942, and January, 1943, findings unchanged. Pelvis soft; no necrosis. March, 1943, pain in left leg. Small hard induration in left parametrium, interpreted as fibrosis because of high central dose. May, 1943, edema left leg. Tender mass felt with difficulty high up in left parametrium by rectal examination. September, 1943, uremia. October, 1943, patient died.

Autopsy showed a large mass in the left parametrium with complete ureteral obstruction; smaller mass in right parametrium with ureteral obstruction and dilatation. Microscopic examination showed carcinoma in both parametria.

As can be seen, the lateral portions of the parametria received an insufficient dose because the treatment was concentrated to the center in view of the endocervical type of the disease. Considering the anaplastic type of the tumor a more complete coverage of the parametria would have been indicated.

Case II. A. N., aged thirty-one. May, 1943. Weight 140 lb. Anteroposterior pelvic diameter 22 cm. Circumference 88 cm. For six weeks vaginal discharge with pain in right lower quadrant. No intermenstrual bleeding. She consulted her physician on account of the vaginal discharge. Biopsy showed an epidermoid carcinoma with only slight degree of differentiation. Profuse vaginal discharge. Cervix showed a scar extending from external os on right toward the right vaginal wall. Tenderness on palpation of parametria, particularly on the right. Carcinoma of cervix, presumably Stage I, with parametritis. Treatment started with roentgen radiation. Total dose 8,950 r in thirty days, using 400 kv. Treatment was then discontinued in order to permit higher radium dose. Cervical tandem 3,960 mg-hr., vaginal ovoids 4,650 mg-hr. In September and November, 1943, cervix of normal size. Pelvis soft on rectal examination. In December, 1943, pain in anterior circumference of right thigh. Pelvis soft. February, 1944, progressing pain and edema of right leg. Mass palpable in right parametrium. Because of previous pelvic infection there was a question of pelvic abscess or recurrent disease. Intravenous urograms showed poor function of right kidney with marked caliectasis. Under observation no marked change in local findings but progression of pain. Since abscess could not be excluded with certainty and aspiration through the vagina was negative, exploration was done which showed a hard carcinomatous mass in the right pelvis. Patient died in June, 1944.

In this case again the parametrial dose was undoubtedly too low because this was considered as a Stage I carcinoma. This was certainly poor judgment. Either roentgen therapy should have been given only in an amount to combat the infection or it should have been carried to a presumably adequate dose, in this case at least 12,000 r.

There remain 4 patients listed as unexplained failures. They all died of parametrial recurrence.

Case III. H. S., aged fifty-three. November, 1935. History of six months' spotting. Stage II. Extension into vaults of the vagina. No parametrial induration. Epidermoid carcinoma, Grade 3. Radium treatment was given consisting of 3,500 mc. (2,500 mc. intrauterine, 1,000 mc. vaginal). Roentgen treatment was given with 800 kv., total dosage of 13,500 r. In Sep-

tember, 1936, the cervix was entirely healed; there were pain and edema of the left leg; parametrial thickening. The patient died in December, 1937.

Case iv. V. B., aged forty. November, 1942. Weight 157 lb. Regular periods until two months ago; since then intermittent flow. Posterior lip replaced by large hard ulceration. Vaults, fornices, parametria soft. Stage ii. Microscopic examination showed squamous carcinoma, Grade 3. Radium treatment consisted of 7,940 mg-hr. (3,900 mg-hr. vaginal ovoids; 4,040 mg-hr. cervical tandem); roentgen treatment 11,100 r in fifty-nine days using 800 kv. Cervical radium after initial 3,800 r because canal could not be entered at first. April, 1943, cervix small, smooth, soft, pelvis soft. September, 1943, pain in right leg. Hard induration in right paravaginal and parametrial area, extending to pelvic brim. Non-functioning right kidney. October, 1943, intolerable urinary frequency, urinary hemorrhage. Cystoscopically large ulcerated tumefaction on right trigonal area, covering right ureteral orifice. This tumefaction, on palpation, was in direct connection with palpable parametrial mass. The patient died.

Case v. A.C., aged thirty-six. June, 1942. Weight 192 lb. Anteroposterior pelvic diameter 24 cm.; circumference 112 cm. Two years ago occasional spotting after intercourse; last two months more marked bleeding. Large ulceration of posterior lip, granular induration of anterior lip. Cervix movable. No infiltration in fornices, vaults or parametria. Stage ii. Microscopic examination showed squamous carcinoma, Grade 3. Radium treatment, 11,610 mg-hr. in twenty-seven days (4,040 mg-hr. vaginal colpostat, 4,490 mg-hr. uterine tandem, 3,080 vaginal ovoids). Roentgen treatment, 13,400 r in forty-four days using 800 kv. October, 1942, cervix soft and smooth. Pelvis soft. February, 1943, pain in left leg. Edema of left leg. Cervix small and smooth; apparently cervical lesion controlled. Parametria on palpation soft. July, 1943, frozen pelvis, block of left ureter. Patient died of uremia.

Case vi. F.D., aged thirty-two. September, 1942. Weight 124 lb. Anteroposteior pelvic diameter 18 cm., circumference 92 cm. Regular periods. For one week continuous intermenstrual bleeding. Had never had intermenstrual bleeding or spotting. Large hard cervix. Slight invasion of left fornix. Parametria soft. Stage ii (ii–iii?). Microscopic examination showed anaplastic squamous carcinoma with infection. Radium treatment, 9,000 mg-hr. (4,000 mg-hr. intrauterine, 5,000 mg-hr. vaginal). Roentgen treatment, 11,650 r in forty-three days, using 800 kv. March, 1943, cervix healed. May, 1943, rectal urgency, thickening of rectovaginal septum, induration with central ulcer in anterior rectal wall, 2 cm. necrosis in left vaginal fornix. September, 1943, pain in left leg. Vaginal necrosis healed, induration of rectovaginal septum disappeared, moderate thickening of both parametria. October, 1943, cervix completely effaced, stenosis of upper vaginal dome, induration in left parametrium to pelvic brim. Left ureteral obstruction. February, 1944, induration of both parametria, beginning uremia. Patient died in March, 1944, of uremia. On autopsy large pelvic mass, frozen pelvis, both ureters dilated to thickness of a thumb.

It seems to us that in these 4 cases the treatment received must be considered adequate according to today's standards. They therefore seem to represent unavoidable irradiation failures.

2. The second question then arises: *Could any of these patients have been saved if they had been treated by radical hysterectomy instead of irradiation?*

Meigs[7] lists the following 5 main reasons which have led him to the "introduction of an old and formidable operation into the treatment of cervical cancer" in his clinic.

1. If the cervix has been removed there is no chance for a recurrence in it.
2. If the cervix has been removed no cervical cancer can regrow in it as a re-occurrence.
3. Certain cancers of the cervix are radioresistant—(a fact proved at the Pondville Hospital where multiple biopsies are performed at the time the X-ray and radium treatment are being carried out).
4. There will be less damage to the bowel if surgery is undertaken. Lately 46 cases of serious bowel injury have been found in our clinics.
5. From the work of both Bonney and Taussig it is obvious that patients with lymph node metastases can be cured by surgery in some instances and the author

believes that it is not possible to cure with radiation cancer in lymph nodes deep in the pelvis.

It does not seem that the reasons listed under 1, 2, and 4 are valid.

That severe bowel reactions for the stages here under discussion can be avoided has already been discussed. A recurrence of an uncontrolled epidermoid cancer or a regrowth of a new cancer in the cervix itself after adequate irradiation is extremely rare. In patients with Stage I and II cancer who died of uncontrolled disease, the cervical lesion itself is almost always controlled. *None of the failures in this series was due to uncontrolled or recurring cancer in the cervix itself.* In our total series of 153 cases of all stages treated since 1935 we have observed one regrowth in the cervix itself after four years' freedom from demonstrable disease in a Stage III carcinoma in a patient seventy years of age.

Nevertheless it does occur and in cases of uncontrolled disease in the cervix itself in spite of adequate therapy this failure must probably be explained by an unusual radioresistance of the tumor as mentioned by Meigs as his third reason in favor of surgery. To quote Lacassagne: "For a certain kind of cell no lethal dose exists; . . . lesions in similar tissues, exposed to the same conditions of homogeneous irradiation do not always show similar results. Only this is definite that there exists no certainty either as to the probability of survival of tissues or a certitude of their destruction by any determined irradiation."

The observation of the cervix itself as the source of failure in adequately treated cases of true epidermoid carcinoma is, however, so rare that it should not enter into an appraisal of clinical probabilities deciding between surgery and radiation therapy. *Active disease in the cervix itself as a cause of failure due to the radioresistance of the tumor should be accepted only after careful analysis of the histopathological findings and of the irradiation record of the individual case.* With the migration to the West Coast, we have seen during the last two years a number of patients treated in different parts of the country, and we have sometimes been impressed by the inadequacy of the treatment they have received. We do not think that a radium dose below about 8,000 mg-hr. (with adequate distribution in space and time) can be considered adequate even if one occasionally seems to obtain results with less. We have also at times seen that interstitial irradiation is still used. With this technique naturally a homogeneous irradiation with a lethal dose throughout the lesion is very difficult to accomplish and problematic and the finding of viable cancer cells in some areas of the cervix, or a regrowth, is not surprising. But this cannot be explained by an unusual radioresistance of the particular tumor. In such cases an improvement of the irradiation technique is preferable to return to radical surgery.

Meigs', as well as Taussig's valid argument for surgery, we find in Meigs' last reason "that it is not possible to cure with radiation cancer in lymph nodes deep in the pelvis." Lymph node metastases from epidermoid carcinoma anywhere are almost never controlled by external irradiation, even in much more accessible areas such as the oral cavity. For this reason surgical dissection has unquestionable preference in the management of the lymphatic area in this type of carcinoma. For the pelvic nodes the situation is even less favorable. In a previous report of the authors with Parker before the Radiological Society in 1940,[2] it was shown that, according to Parker's careful measurements, the dose delivered with 800 kv. roentgen rays using 3,500 r (measured on the skin) through each of two anterior and two posterior 10 by 14 cm. fields to a point of the soft tissue inner pelvic wall at about the mid-attachment of the broad ligaments reaches approximately only 2,600 r in a large pelvis (26 cm. diameter), 3,000 r in a medium pelvis (22–24 cm.) and 3,500 r in a small pelvis (20 cm.). The isodose curve computed for the combined contribution of 8,000 mg-hr. radium with roentgen rays as described showed that at

this same point in small pelves only a total dose of 4,500 r is reached. This dose seems too small and from our experience with other epidermoid lymph node metastases we can hardly expect a sterilization of the peripheral pelvic nodes. A further increase of this dose in an amount necessary to expect even a marked fibrosis of those nodes with prolonged retardation of their growth is, as experience has shown, not possible without intolerable damage to the pelvic vascular connective tissues and severe intestinal reactions.

It seems from clinical observation and from analogies that radiation therapy can control pelvic disease beyond the cervix if it represents a diffuse direct invasion through the lymphatics of the broad ligament but not disease in the lymph nodes. (We are of course never certain how much of a palpable pelvic infiltration is due to true cancerous invasion, how much to infection, and how much to fibroblastic response of the tissue to progressing cancer.) Therefore, apparently extensive disease of Stage III can be controlled in a certain percentage of cases while apparently less advanced stages in which the involvement of peripheral pelvic nodes cannot be demonstrated by palpation develop parametrial disease from these uncontrolled lymph nodes. At least 2 of our 4 cases listed as unexplained failures probably fall in this group (Cases IV and V). This is suggested by the fact that pain and edema of the leg preceded the demonstrable pelvic induration by many weeks, probably indicating that the recurrence started from a higher node and became palpable only after the induration was in reach of the examining finger. The other cases probably belong in the same group but the appearance of demonstrable induration coincided with the appearance of pain.

Admitting, then, that there is a small group of cases for which a permanent cure with our present methods of radiation therapy is unlikely but for which, a priori, a better surgical chance could be expected, *the question arises as to their actual chances if surgery is used.*

Two procedures are available. Taussig recommends for Stage II cases a combination of radiation therapy to the cervix and its immediate neighborhood in conjunction with iliac lymphadenectomy. There are two objections to this type of therapy. One is the fact that no attempt is made to remove the lymph nodes around the lower portion of the ureters because this would make the operation considerably more complicated and risky, and because it is assumed that the irradiation should take care of the lymphatics in this area. While it is true that the dose in this area is considerably higher than the one in the peripheral portions of the pelvis, mainly because of the addition of the radium dose, it still remains questionable whether a complete sterilization is likely. This might be possible for some lymph nodes in cases of less differentiated carcinomas. But in these less differentiated carcinomas, we have to expect a more generalized spread through the lymphatics and surgery would not take care of this. On the other hand, and this is the second objection, every procedure where radiation therapy and surgery are applied to the same field is bound to affect either procedure to a certain degree. We believe that after intensive radiation therapy by a combination of a maximal radium and a maximal roentgen-ray dose, a procedure such as iliac lymphadenectomy carries considerable risk. This method was patterned after the combined treatment, for instance, of oral carcinomas, where radiation therapy to the primary lesion together with a block dissection of the lymphatics is unquestionably the procedure of choice. But surgery here is applied to an area which has not received any irradiation, and furthermore a complete block removal is done, while such is not the case in the type of operation recommended by Taussig.

For these two reasons, it seems questionable whether viewed statistically the procedure will accomplish as much as either

radical hysterectomy or intensive radiation therapy alone, although it is admitted that occasional cases in which only the more peripheral pelvic nodes are involved may be saved, while they would not be controlled by irradiation. The statistical evaluation of Taussig's results in which he computes a 68 per cent greater salvage than by irradiation alone seems erroneous. His five year survival rate with the combined procedure is 38.6 per cent against 22.9 per cent in Stage II cases treated by irradiation alone. By analyzing the irradiation procedure used for comparison with his, we find that the irradiation applied in this series has been greatly improved throughout the years, implicitly admitting the inadequacy of radiation therapy in former years. Yet these earlier cases are apparently included in the material for comparison. This probably explains the low survival rate of 22.9 per cent of the cases treated by irradiation alone as compared with the possible survival rate of 40 to 60 per cent for Stage II accomplished elsewhere. As has been seen, a survival rate of 70 per cent can be attained in correctly irradiated cases of Stage II (Table II).

Taussig found cancerous involvement of the removed glands in 26.8 per cent of 175 Stage II cases operated upon. Twenty-one per cent of those with demonstrated metastases showed a five year cure rate. In other words, the operation was found to be necessary in 1 out of 4 in whom it was performed, and 1 out of 5 of those in whom it was necessary was cured. This means 1 out of 20 patients in whom the operation was done was saved by the procedure. Nineteen out of 20 patients were not benefited by the procedure and in all likelihood some of these could have been salvaged by a more radical radiation therapy applied without the allowance for the anticipated later surgery. The situation, of course, would be different if it were possible to recognize these cases before any treatment is instituted. As far as our 4 patients under discussion are concerned, each one would have had a chance of 1 to 5 to be salvaged, but I doubt that after the intensive irradiation they received the procedure would have been feasible without grave complications.

It seems quite logical that if surgery is done it should be in the form of the radical Wertheim operation without considering radiation therapy. Meigs, prompted by his disappointment in radiation therapy, has recently revived this classical procedure. He has operated upon 65 cases without a single death. The improvement of modern surgery during the last decade, particularly in combating shock and infection, will certainly contribute to the reduction of the primary mortality. Bonney,[1] probably one of the best gynecological surgeons who has done this operation on a large scale, has an average primary mortality of 10 per cent, but it seems that he accepts for the operation cases more advanced than those selected by Meigs, as indicated by the findings of actual cancerous node involvement in 17 per cent in Meigs' group as against 40 per cent in Bonney's group.

Of the 65 patients operated upon by Meigs[9] 53 had no cancerous lymph node involvement. Two of these are dead. In 12 cases positive lymph nodes were found. Three of these are dead. Interpreting these results, we can say that so far (provided that the still living patients will remain alive) out of a group of 65 patients, 9 were saved who would not have been saved by irradiation, granting that radiation therapy cannot sterilize lymph node metastases. *This means 20 patients have to be subjected to this radical operation in order to save 3 that could not have been saved otherwise.*

Meigs' requirements are very strict. Ideally, the patient should be thin, young, in good health, and have an early cancer. Under these requirements, it seems that out of the 4 cases in our group which were not saved by radiation therapy only 1 (Case IV) would have been acceptable. Case V, a patient weighing 192 pounds and with a pelvic diameter of 24 cm., would have been refused on account of adiposity. Case II

had an accompanying parametrial infection prior to treatment. Case III had a duration of symptoms of six months with a beginning extension into the vaults and the case probably would not have been considered by him as early carcinoma. But it is just for the cases in the more advanced Stage II in which increased size of the disease and increased duration, the likelihood of peripheral lymph node involvement is higher and therefore the chances of irradiation cure lower, where surgical help may be considered, and in this group we know from extensive studies that the primary operative risk rises and the cure rate decreases. The 4 cases in our series for which in retrospect we might have considered surgery were well developed Stage II. No Stage I was found in this group.

"Very early carcinomas" (early Stage I) have an excellent chance of permanent cure by radium only with one week hospitalization and no subsequent morbidity due to the treatment itself. For this type of case a procedure of the magnitude of the Wertheim operation seems not to be necessary. In recognition of this fact, Taussig has not suggested his combined procedure for these cases but only for Stage II cases.

Concluding, we must admit that there is a group of cases of epidermoid carcinoma of the cervix with peripheral lymph node involvement in the pelvis in which, on the basis of clinical experience and conclusions from analogies, radiation therapy apparently will not accomplish a cure and in which theoretically surgery would be more promising. In our own series 4 cases out of 79 belong in this group. Three of these cases would not have been accepted for surgery according to Meigs' rigid standards. In Meigs' own series 9 patients belong in this group out of 65 on whom he operated. This means 3 out of 20 would be saved while 17 would be subjected to unnecessary surgery.

Whether under these circumstances the indication for the Wertheim operation is considered acceptable is of course a matter of personal opinion.

Since it is impossible to recognize these cases prior to treatment, it is most likely that from a statistical point of view the actual survival rate by surgery would be smaller than if radical radiation therapy were instituted. The survey of our own material has shown that more cases were not controlled by irradiation because of some avoidable inadequacies of treatment than would have been saved by surgery of cases essentially unsuitable for irradiation. The analysis of Lacassagne's failures suggests the same conclusion. We are forced to admit that improvement of radiation therapy by more careful attention to details of technique, by the elimination of inadequate procedures of the past and by the careful adaptation of the procedure to the individual requirements will probably save more patients than a return to surgery. But we should be grateful to the surgeons for awakening us from our satisfaction with past accomplishments and for stimulating our desire for improvement.

REFERENCES

1. Bonney, V. Treatment of carcinoma of cervix by Wertheim's operation. *Am. J. Obst. & Gynec.*, 1935, *30*, 815–830.
2. Cantril, S. T., Buschke, F., and Parker, H. M. Irradiation in cancer of cervix uteri. *Radiology*, 1941, *36*, 534–542.
3. Cutler, M., Buschke, F., and Cantril, S. T. Irradiation or surgery in carcinoma of the cervix? In: Cancer, Its Diagnosis and Treatment. W. B. Saunders Co., Philadelphia, 1939, pp. 396–401.
4. Franz. Quoted by Wille.[12,13]
5. Lacassagne, A. Die relative Bedeutung der Ursachen für den Erfolg oder das Felsehlagen bei der Radiotherapie der Collumepitheliome. *Strahlentherapie*, 1929, *32*, 434–440.
6. Lacassagne, A. Results of treatment of cancer of cervix uteri. *Brit. M. J.*, 1932, *2*, 912–913.
7. Meigs, J. V. Carcinoma of cervix—Wertheim operation. *Surg., Gynec. & Obst.*, 1944, *78*, 195–199.
8. Meigs, J. V. Medical progress: gynecology; carcinoma of cervix. *New England J. Med.*, 1944, *230*, 577; 607.
9. Meigs, J. V. Personal communication.
10. Regaud, C. Quelques problèmes relatifs au traitement radiothérapique des épithéliomas cervico-utérins. *Cancer, Bruxelles*, 1935, *12*, 93–112.

11. Taussig, F. J. Iliac lymphadenectomy for group II cancer of cervix; technique and 5 year results in 175 cases. *Am. J. Obst. & Gynec.*, 1943, *45*, 733–748.
12. Wille, F. C. Ergebnisse der operativen Behandlung des Collumkarzinoms an der Charité-Frauenklinik in den Jahren 1916–1920. *Zentralbl. f. Gynäk.*, 1927, *51*, 18–21.
13. Wille, F. C. Die Strahlentherapie des Collumkarzinoms an der Charité-Frauenklinik und ihre Ergebnisse. Bericht über die Jahre 1915–1920. *Zentralbl. f. Gynäk.*, 1927, *51*, 2849–2856.
14. Wirth, J E., Cantril, S. T., and Buschke, F. Analysis of failures of radiation therapy in carcinoma of cervix uteri. *Radiation Therapy, Tumor Inst., Seattle*, 1940, No. 1, pp. 12–21.

DISCUSSION

Dr. Charles L. Martin, Dallas, Texas. Drs. Buschke and Cantril have raised a question in which gynecologists are much interested at the present time. Should favorable Stage II cases of cancer of the cervix be subjected to radical surgery? Meigs, of Boston, has revived the interest of surgeons in this problem by performing the Wertheim operation on a series of 65 such patients, with no immediate mortality, whereas, in bygone days the surgical mortality in various clinics varied from 15 to 30 per cent. He does the operation in an effort to remove pelvic nodes which may contain metastases.

Our experience with neck dissections has taught us that success depends on the block removal of all the lymphatics and nodes in a given area. The block removal of the lymphatics on either side of the uterus traversed by the delicate ureters is a very difficult procedure, and even though Meigs' patients survived the severe shock of the operation, many of them had serious postoperative complications, principally ureteral damage. Such sequelae may be justified if five year statistics prove that the salvage is markedly improved by such a radical procedure, but I feel that we should not swing back to radical surgery until convincing statistics are available. It seems unfortunate that the publicity given Meigs' work has induced many surgeons, who do not possess his skill, to resume the surgical care of all patients with cancer of the cervix.

One of his reasons for using the operative procedure was his observation that many of his own cases, receiving radiation therapy, developed serious intestinal damage. Results published by our own clinic, as well as those of Lenz, and others, indicate that good results can be obtained without such sequelae.

Dr. Juan A. del Regato, Columbia, Missouri. Drs. Buschke and Cantril must be congratulated for their very careful analysis and for their timely warning.

Ten years ago I participated in what we thought was the closing chapter of this controversy of surgery versus radiotherapy in early carcinoma of the cervix. I refer to the memorable session of the French Academy of Medicine and the argument between Regaud and J. L. Faure. It appeared then obvious that radiotherapy, properly done, was superior to the Wertheim operation in the treatment of early carcinomas of the cervix.

This controversy has been recently revived in this country by the surgeons as well as by the radiotherapists who were not satisfied with their own results. Worthy of comment is the report by Dr. Jones of the Kelly Clinic in Baltimore who reported a very interesting experiment. In his clinic the very early carcinomas of the cervix, Stage I, were operated upon and the more advanced Stage I cases were treated with radiotherapy. After a number of years the percentage of results for those treated with radiotherapy was superior to that obtained with surgery although the choice of cases was favorable to surgery.

We must not lose our sense of proportion in this controversy. The number of cases to which this is limited is very small. Healy reported in the late 1920's a classification of 1,500 cases of carcinoma of the cervix, only 12.5 per cent of which were operable. We have now a classification of carcinomas in four stages which corresponds better to the prognosis of the different cases. This classification gives an average of 10 to 12 per cent of the Stage I cases.

It remains that at best only 80 per cent of the carcinomas of the cervix, Stage I, are cured by irradiation and it is interesting to analyze whether the 20 per cent of failures could be reduced.

Local recurrences of carcinomas of the cervix are the exception. Few carcinomas of the cervix are actually resistant to proper treatment. Most post-irradiation recurrences occur in the parametrium. I agree with Drs. Buscke and Cantril that the technique of treatment chosen is most important and insufficient doses will of course give local recurrences. Interstitial irradiation will be the cause of radionecrotic damage to the

bowel and other structures which may account for the loss of the patient.

As far as the proportion of lymph node involvement in early carcinoma of the cervix is concerned, it must be stated that many authors have reported as metastatic implants the presence of adenoid epithelial structures in the iliac nodes. This is obviously an error. Those epithelial structures are only important if they present an epidermoid differentiation, or definite evidence of malignancy.

When a carcinoma of the cervix is irradiated and a surgical excision follows immediately, the presence of carcinoma in the removed specimen is no proof of radiotherapeutic failure. This will also be the case in a basal cell carcinoma of the skin which would be excised shortly after radiotherapy. The latent period between the administration of radiation treatment and the complete disappearance of the tumor increases with the differentiation of the tumor.

The argument of late recurrences in carcinoma of the cervix is not strong. Regaud analyzed a series of 500 cases which had recurred after irradiation and only 1.5 per cent of them had recurred after five years.

The main argument remains that of losing the patient through radionecrotic effects on the bowel and other normal structures. One cannot consider the percentage of such accidents on an over-all group to be of significance in the restricted group of early carcinomas of the cervix.

In closing, I believe that if a comparison of surgical and radiotherapeutic results is to be done again, the good surgical results should be compared with the good radiotherapeutic results.

Dr. Buschke (closing). The question of dosage is of course always unsatisfactory in a discussion unless one can qualify the details of the technique used. With regard to a question as to our roentgen-ray doses, I would like to integrate the consideration of roentgen-ray doses in the entire treatment schedule and therefore discuss it together with the details of our radium technique.

The doses mentioned are planned on the basis of what is now more generally known as the French technique. This means the radium is given for a period of approximately ten days with the dose divided: 4,000 mg-hr. in the cervical canal and 4,000 mg-hr. in the vaginal vault. The roentgen treatment is given through two straight anteroposterior and two straight posteroanterior fields. This means the beam is not converging toward the cervix because we feel that the adequate radium dose has taken care of the primary lesion. I think that this application of straight fields with the protection of a small central area is one of the reasons why our intestinal reactions are not as marked as they apparently sometimes are observed by others. The dose given to each of these four fields is approximately 3,000 to 3,500 r, measured on the skin, giving a total dose of 12,000 to 14,000 r, depending on the patient, delivered in approximately six weeks.

Now, if I say this is a standard technique, this should not be misinterpreted because this basic procedure is subject to considerable variation depending on the individual case, and I do not think that we treat more than 2 out of 10 patients with this actual standard procedure.

The individualization applies to roentgen as well as to the radium therapy and to their time relationship. We believe that the attention to minute details and careful adaptation of the technique to the individual requirements are necessary to avoid dangerous reactions and yet to push the dose to the limit of tissue tolerance. The radium containers are inserted under anesthesia if the patient is apprehensive or if a better relaxation of the vagina under anesthesia is anticipated. With less apprehensive patients and a larger vagina, sometimes the application of vaginal applicators in knee chest position is preferable because in this way the distance between the radium carrier and the rectal mucosa can be increased.

With such attention to details, we have given doses up to 12,000 mg-hr., but I certainly would not recommend this as a standard procedure. However, I believe there is no standard procedure. Certainly a dose of 8,000 mg-hr. would be too high if, for instance, the entire treatment were given in three days. We purposely use applicators with a low radium content. We do not have more than 40 mg. or at the very most 50 mg. in the tandem, and 20 or 25 mg. at the most in each of the vaginal applicators. This content depends also partly on the size of applicators that can be introduced. In this way we deliver the required dose in approximately 100 hours, distributing the entire treatment with radium over about ten days. More frequently, we permit an interval of

about eight to ten days between the vaginal and cervical applications. Again depending on the anatomical findings, we might increase the vaginal dose and correspondingly decrease the cervical dose, or vice versa. Likewise the roentgen procedure is adapted to the individual requirements as indicated by the clinical findings. The dose over one parametrium may be increased with a corresponding adjustment of the total dose. In other cases again, particularly those with vaginal extension, the beam might be convergent toward the vagina with corresponding adjustment of the radium dose to allow for the increased rectal reaction.

In short, we attempt to adjust the technique as carefully as possible to the individual requirements. It goes without saying that no detail of this procedure (including the daily placing of the patient for roentgen therapy) is executed by anyone but the radiotherapist who has the patient under his permanent care. No division of efforts is permitted.

With regard to the question of whether the Taussig lymphadenectomy gives any additional advantage, I refer to the discussion in the printed paper as submitted for publication. Time does not permit me to go into these details here.

A SLIDE RULE FOR DETERMINATION OF DOSAGE FROM LINEAR RADIUM APPLICATORS

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IN SUPERFICIAL or interstitial radium therapy it is sometimes necessary to determine the dose delivered by a single needle or tube. In interstitial treatments of very small lesions the dose must be determined from the contributions of individual needles at the point of interest. For instance, a technique for the treatment of the lips which is extensively used at this Hospital is the implantation of two parallel needles of sufficient length which are inserted about 1 cm. apart. The dose delivered to the lesion can then be related to the dose at the center between the needles.

The point at which the dose is to be determined is generally situated opposite the center or active end of a needle. For other locations the needle can always be divided into two parts so that the point considered lies opposite an active end of each and the dose is then composed of two contributions from each needle. For a linear applicator the effect of oblique filtration is not negligible and depends on the ratio of the distance from the needle to its active length. Besides, the needle can be filled with radium or with radon and the relatively quick decay of the latter must be allowed for.

Several methods are available[1,3,4,5,6] to determine the dose delivered by a filtered linear source. They are based on the use of different tables or diagrams and all require some additional though not difficult calculations. A nomogram that could completely represent the relation between the quantities involved would be very complex because of the great number of variables and also because the filtration effect is not independent of other variables. It was found possible, however, to design a multiple slide rule which not only represents the relation between all variables but which is also simple to use. In addition, it permits quick solution of numerous other problems which occur in dosage calculations.

The instrument is based on Sievert's formula and tables[5,6] and is shown in Figure 1. The essential theory of it is given in the appendix. The quantities involved are represented on scales, and by moving the slides these can take up any position relative to each other. All slides must be set so that those divisions corresponding to the problem at hand are opposite to each other on adjacent scales. Where transfer marks only are provided these must be used for setting the slide. The range of all scales is sufficient to cover any case that may occur under normal therapeutic conditions.

Starting from the top, the first scale which is fixed to the main body of the instrument refers to the activity of a needle in milligrams of radium. If radon is used the figures give the number of initial millicuries. The first slide is set under it; it carries the two necessary time scales for radium and radon respectively, and also an upper and lower transfer mark. The upper (radium) scale must be used in conjunction with the lower mark, and vice versa. The next slide carries identical scales on its upper and lower border and shows active length. There are two notations: the ordinary figures must be used if the dose is determined at a point opposite the center of the needle, while the figures in brackets refer to points opposite the active end.* The following slide has only one scale for distance from the needle axis. On its lower border a transfer mark leads to a line system without notation. It is only necessary to follow the lines from the transfer mark to the lower border and set the next slide

* The dose opposite the center of a needle equals the dose opposite the active end of another needle of same total radium content but one-half its active length.

under the point thus obtained. The part carrying this line system is rigidly connected with the active length scale and thus forms a holder for the intermediate distance scale. The principle of extending one of the slides into a complete slide rule permitted the solution of the problem that one of the factors contributing to the dose was itself a function of several variables. This auxiliary slide rule computes that function and the result is linked with the main slide rule over the transfer line system. Before discussing but it should be kept in mind that the gamma-ray dose only is determined, while for extremely low filtrations a great amount of beta radiation may also be present; the dosage contribution of the latter is not considered. The filtration effects have been calculated on the assumption of a mean absorption coefficient for platinum of 2.0 cm.$^{-1}$ as given by Sievert.[5] In view of a recent paper by Mayneord and Honeyburne[3] a value of 1.5 cm.$^{-1}$ might be more accurate although the difference for medi-

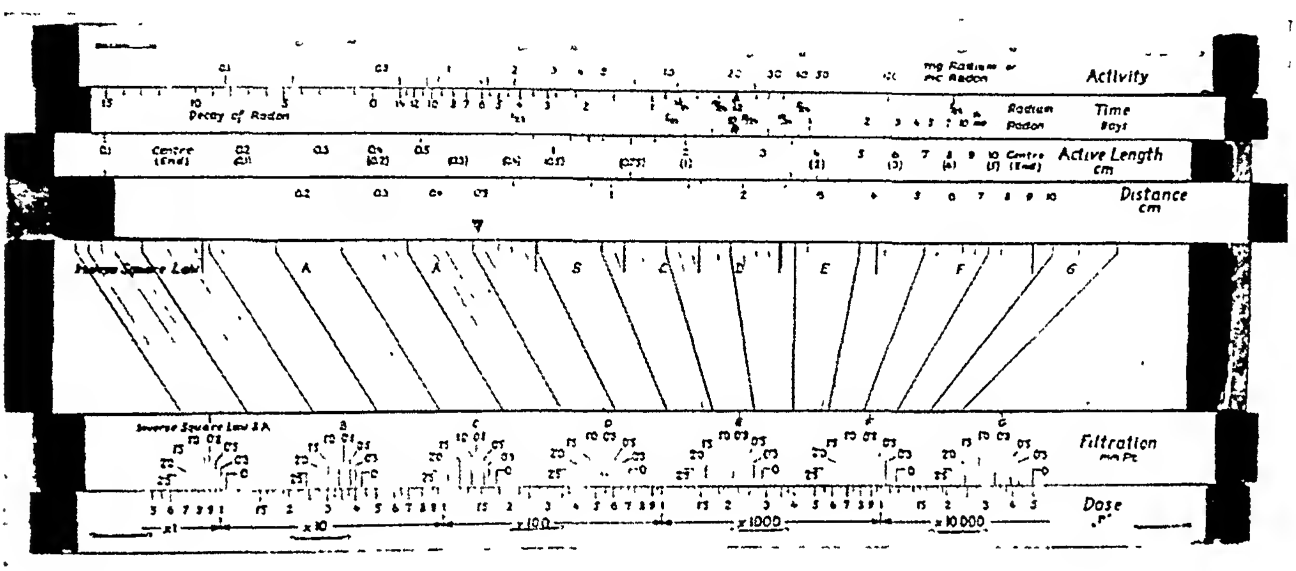

Fig. 1. Photograph of the slide rule (for description see text).

um filtrations is very small indeed. The filtration scales which are very short are arranged side by side on the slide omitted from the discussion before. They are marked *A*, *B*, *C*, . . . *G* respectively. The upper border of the transfer line system is subdivided into corresponding sections *A*, *B*, *C*, . . . *G* according to the ratios of distance to active length. The transfer mark of the distance slide is also used to indicate which filtration scale must be used.

the next slide which refers to filtration we assume that it is omitted altogether and go straight on to the last scale which again is fixed to the main body of the instrument and gives the dose in roentgens. The instrument described so far (omitting the filtration scale) represents the relation between the variables for a fixed filtration of 0.8 mm. of platinum. For other filtrations a correction factor has to be applied which, as mentioned before, also depends on the ratio of distance to active length. The correction is comparatively small and it is possible to use a constant correction factor within a limited range of the ratio without introducing an appreciable error. The whole range of all possible ratios was divided into a number of such sections and a complete filtration scale was provided for each. These scales include zero filtration

For distances greatly exceeding the active length the transfer line system would have to extend very far to the left. In these cases, however (distance greater than three times the active length), the dose does for practical purposes not depend anymore on active length and can be worked out according to the inverse square law for point sources. A section marked "Inverse Square

Law" has therefore been added within which any selected active length will give the same result. In this section all transfer lines have become parallel. A change of the active length will cause the active length scale and with it the transfer line system to be moved in one direction while the distance scale is moved by the same amount in the opposite direction. Because of the parallelism of the line system the effects of these two movements will just cancel each other so that the same result is obtained whatever active length may be chosen. In this way it was possible to reduce the extent of the line system to that of the other scales.

The dose in roentgens was computed on the assumption that the specific emission of gamma rays from radium was 8.0 r/mg-hr. at 1 cm. distance from a point source filtered by 0.5 mm. Pt. So far, no general agreement about this figure has been reached but other values could easily be allowed for, e.g., by a slight shift of the transfer marks on the filtration slide.

The sequence of slide settings can be chosen at will. That means that any quantity can be determined if all the others are known. Furthermore, any setting of two adjacent scales gives a whole series of corresponding values which will yield the same result if all other factors are kept constant, and it is thus possible to solve many interesting part-problems. If the quantities one is interested in are not on adjacent scales, any arbitrary values on the intermediate scales can be chosen, as long as they are kept constant. Sometimes it may be more convenient to alter the succession of slides which can be introduced even in reversed direction without affecting the result. In the following, a few problems are stated which all can thus be solved in a few seconds: A radon implant gives the required dose in, say, 7 days; how much radon must be used to give the same dose in 5 days?—If a treatment was planned for radium, how much radon would be required to give the same dose in the same time?—Variation of dose from a given needle with distance—Relation between active length and dose, other factors remaining constant, etc.

The instrument permits immediate determination of the dose at points opposite the center and opposite the active end of a needle. Usually, knowledge of the dose at these points is quite sufficient, but the dose at other points can be worked out by the following method. The needle is divided into two parts where the dividing point is opposite the point considered. For each part, the dose can be worked out separately and the total dose is simply the sum of the two contributions. For points outside the active ends, a similar difference method can be applied which, however, is apt to become highly inaccurate when the difference of the contributions becomes small compared with the contributions themselves.

Sometimes a radon applicator cannot be used at the specified time and if the delay is considerable, loss of strength due to decay must be allowed for. For such calculations a short scale marked "Decay of Radon" was added at the upper border of the first slide (treatment time). If the zero point of this scale is set under the number of initial millicuries of radon, then the amount remaining after a certain time can be read off opposite the corresponding scale division.

A few details on the construction of the slide rule might be of interest. The scales were drawn at a somewhat increased size and then photographically reduced to final size. (The slide rule is 10 inches long.) The negative was taken with a commercial reproduction camera* and ordinary contact prints were obtained from it. The prints were kept flat during drying and no difficulties due to irregular shrinking of the paper were encountered. The body of the slide rule was made up of thick cardboard as used for packing of roentgen films and glued together with office paste. To prevent the slides from falling out, the top was covered with a sheet of clear roentgen film base

* The author is indebted to Mr. V. Veitch for the preparation of this negative.

attached by a number of wire staples. The scales were protected by two coatings of celluloid varnish and the rest of the cardboard surface was similarly treated with shellac.

The accuracy obtainable with this rather crude model is of the order of a few per cent which is quite sufficient for clinical work. After several years of extensive use, the instrument is still in perfect condition.

APPENDIX

While graphical representation of the relation between two or more variables is widely used, slide rules designed for one particular problem are relatively rarely found. The reason probably is that the making of a slide rule involves a good deal more work than an ordinary nomogram and it cannot be as easily reproduced as the latter. On the other hand, a nomogram for more than three variables can become very confusing while a slide rule does not lose its clearness when the number of variables is increased. The extended slide rule principle used will now be described in general form and then applied to the special problem.

Figure 2 illustrates the slide rule principle for relations between four variables p, q, r and s. There are four scales, one for each variable, which are drawn in such a way that the distance of a point denoted by p from the scale origin o is given by $P(p)$ where P is some function of p. The same applies to the other variables. From Figure 2 the basic relation can be read off immediately

$$S(s)=P(p)-Q(q)+R(r). \qquad (1)$$

Any relation between four variables that can be brought into the form of (1) is therefore suitable for representation by such a slide rule. Naturally, this also includes relations of the form $Y(y)=A(a)\cdot B(b)\cdot C(c)$ because they can be reduced to form (1) by taking the logarithm of the whole equation and then putting log $A=P$, etc. It is very easy to extend the number of variables by adding one or more slides, carrying the necessary scales. Generally, this type of slide rule is suitable to represent any relation of the form

$$Y(y)=A(a)\cdot B(b)\cdot C(c)\cdot D(d)\cdots. \qquad (2)$$

In equation (1) or (2) all variables are distinctly separated. It may occur, however, that one of the functions is itself a function of two or more variables and the relation to be represented can be written as

$$Y(y)=A(a)\cdot B(b)\cdot C(c) \cdots Z[E(e)\cdot F(f)\cdot G(g)]. \qquad (3)$$

If we denote

$$z=E\cdot F\cdot G \qquad (4)$$

then equation (3) is already in the form of (2) but z has to be worked out separately. This can

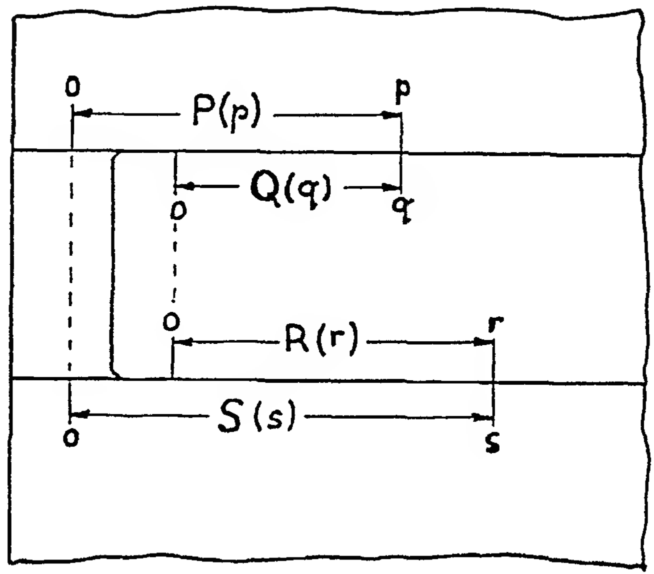

Fig. 2. Basic form of a slide rule showing relation between four variables of the form $S(s)=P(p)-Q(q)+R(r)$.

be done by using the same slide rule principle again and Figure 3 shows how the two systems can be combined in one instrument. The slide of Figure 2 is extended to a complete slide rule to work out relation (4).* The obtained value of z must be transferred to the main system to conclude the calculation. Generally, one will not be interested in the actual value of z or $Z(z)$ so that the notations can be replaced by a system of lines connecting points of equal z values. Since these lines connect points wherever they may be situated, it follows that the two systems are completely independent of each other and convenient different units of length can be chosen in each. It is thus possible to adjust the relative length and position of the two z-scales so that the resulting transfer line system will not be excessively oblique.

* Several slides would be required if Z should be a function of more than three variables.

The dose from a radium needle at a point opposite its center was given by Sievert[5,6] as

$$D=\frac{2MTN}{la}\cdot F(\mu d,\, l/2a) \qquad (5)$$

where M is the radium content, l the active length, T the time, a the distance from the needle axis and μ the absorption coefficient of the wall material of thickness d. N is a conversion constant to obtain the result in roentgens† and $F(\mu d,\, l/2a)$ represents an intractable integral, tables for which have been published by Sievert[5,6].

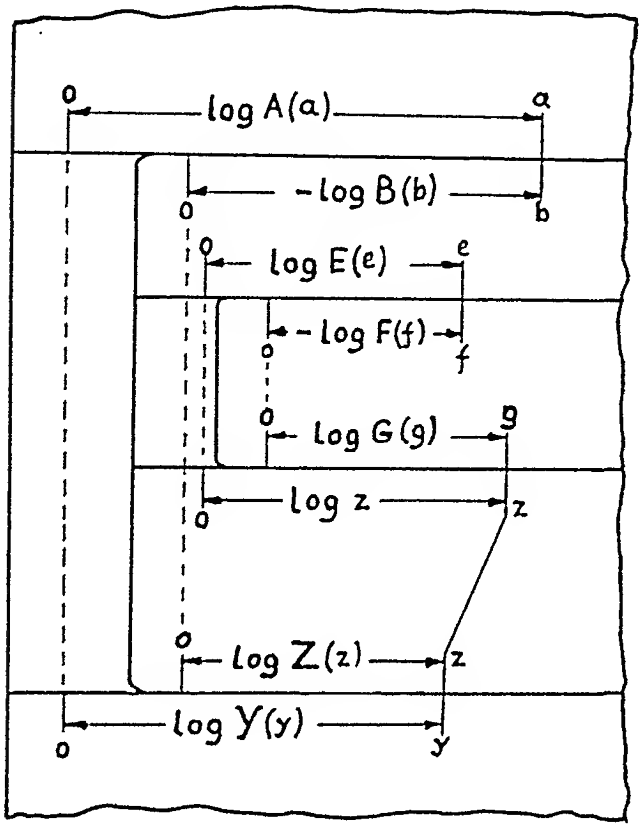

Fig. 3. Extended form of slide rule showing relation between six variables of the form $Y(y)=A(a)\cdot B(b)\cdot Z[E(e)\cdot F(f)\cdot G(g)]$. (The negative signs, e.g. $-\log B(b)$, are necessary because subtraction of a logarithm corresponds to division, subtraction of a negative logarithm, therefore, corresponds to multiplication.)

In the stated form, equation (5) cannot yet be represented by a slide rule as F is a function of two parameters, μd and $l/2a$. This difficulty was overcome by giving μd a constant value corresponding to a medium filtration of 0.8 mm. Pt and allowing for other filtrations in form of a correction factor as described in the main text. It will further be seen that both l and a occur not only as parameters of F but also as independent factors. It might appear, therefore, that each system would have to contain scales for l and a which would greatly reduce the value of the slide rule. In this particular case, however, a solution is possible where no scales are repeated. Rearranging (5) and at the same time giving d the value of 0.08 cm. gives

$$D_{0.8Pt}=\frac{M\cdot T}{l^2}\cdot P(l/2a), \quad \text{where}$$

$$P=4\cdot N\cdot l/2a\cdot F(0.08\mu,\, l/2a). \qquad (6)$$

Equation (6) has the form of (3) but l still occurs twice. The two required l-scales have been placed at the position corresponding to the b- and e-scales in Figure 3, and since the units of length in the two systems are independent of each other the two l-scales which are logarithmic scales can be made identical in spite of the different powers of l involved, so that really only one scale appears on the slide rule. By this method the units of length in the two systems have been disposed of and the transfer line system must be accepted in whatever form it appears. It turned out to be very satisfactory. The g-scale of Figure 3 is reduced to a single transfer mark as P depends on two variables only.

Needles are frequently filled with radon which decays relatively quickly. The factor T in (5) or (6) must then be replaced by $(1-e^{-\lambda t})/\lambda$ to allow for the decay where $\lambda=0.181$ days^{-1} is the decay constant of radon.

The scale for "Decay of Radon" (Fig. 1) is of course derived from the formula $Q=Q_0\cdot e^{-\lambda t}$ where Q is the amount of radon remaining after a time T if the initial amount is Q_0. This can be represented by a simple application of the basic slide rule principle in Figure 2. The s-scale is identical with the p-scale and the r-scale is not required because there are only three variables. The s- and p-scales can therefore be combined in a single scale.

In order to obtain a convenient arrangement of the scales it becomes necessary to introduce suitable constant factors in the formula without, however, altering the result, e.g. multiplying both sides of (6) by 100. The D-scale is then [illegible]

† N is the specific emission of gamma rays from an unfiltered point source [illegible]

placed by a scale for 100 D while on the right hand side the factor 100 can be combined with any of the functions. With logarithmic scales this merely corresponds to a shifting of the scales and a few trials will soon give a good arrangement. The ultimate design is described in the main text.

The author wishes to express his thanks to Dr. Sylvia Bray, Radium Registrar at this Hospital, for the continuous interest shown in this work.

SUMMARY

A multiple slide rule is described which permits quick calculation of the dose delivered by radium or radon needles as used in gamma-ray therapy. It can also be used for rapid determination of relations between quantities effecting the dose. The theory of the design is outlined and some details are given regarding the mechanical construction of a simple model. The accuracy obtainable is sufficient for clinical use.*

REFERENCES

1. LAURENCE, G. C. Intensity and dosage near radium needles. *Radiology*, 1935, *25*, 166–181.
2. LIPKA, J. Graphical and Mechanical Computation. Wiley, New York, 1918.
3. MAYNEORD, W. V., and HONEYBURNE, J. Physical study of intracavitary radium therapy. AM. J. ROENTGENOL. & RAD. THERAPY, 1941, *45*, 235–249.
4. PATERSON, R., and PARKER, H. M. Dosage system for gamma ray therapy. *Brit. J. Radiol.*, 1934, *7*, 592–632.
5. SIEVERT, R. M. Die γ-Strahlungsintensität an der Oberfläche und in der nächsten Umgebung von Radiumnadeln. *Acta radiol.*, 1930, *11*, 249–301.
6. SIEVERT, R. M. Eine Methode zur Messung von Röntgen-, Radium- und Ultrastrahlung nebst einige Untersuchungen über die Anwendbarkeit derselben in der Physik und der Medizin. *Acta radiol.*, supp. 14, 1932, pp. 1–179.

* After posting the manuscript of this paper, a publication by B. S. Wolf on "Radium Dosage for Linear Sources" became available to the author (AM. J. ROENTGENOL. & RAD. THERAPY, 1943, *50*, 400–405) and this paper should also be referred to here. Particularly the method of obtaining filtration correction factors as applied to the slide rule is an extension of the principle described by Dr. Wolf.

A NOMOGRAM FOR THE EVALUATION OF INTERMITTENT RADON TREATMENT

By G. RUDINGER, Dipl. Ing., A. Inst. P.
Physicist, Radium Department of Sydney Hospital
SYDNEY, AUSTRALIA

IN THE use of superficial applicators certain rules regarding the distribution of radium should be adhered to to ensure uniform irradiation of the area treated. Available radium needles with their long inactive ends will often not fit a given area and are particularly unsuitable for strongly curved surfaces. Radon needles or small pieces of capillary are much more satisfactory as they can be obtained at any strength required and are active over practically their whole length.

Whenever possible, it is desirable to treat patients as outpatients for a number of hours per day. In the case of radon applicators it is rather cumbersome to evaluate the treatment time which is equivalent to that for a radium applicator of equal initial strength. For this reason a nomogram was designed to permit the quick solution of the problem. In Figure 1 the left scale represents treatment time per day while the right scale shows the number of days. A straight line connecting the proper scale divisions intersects the middle scale at a point showing the equivalent hours (sometimes also called milligram-hours per initial millicurie). For example, a radon treatment of 8 hours per day over 5 days is equivalent to 28.5 hours using radium of equal initial strength. It is seen that the same equivalent hours could also be ob-

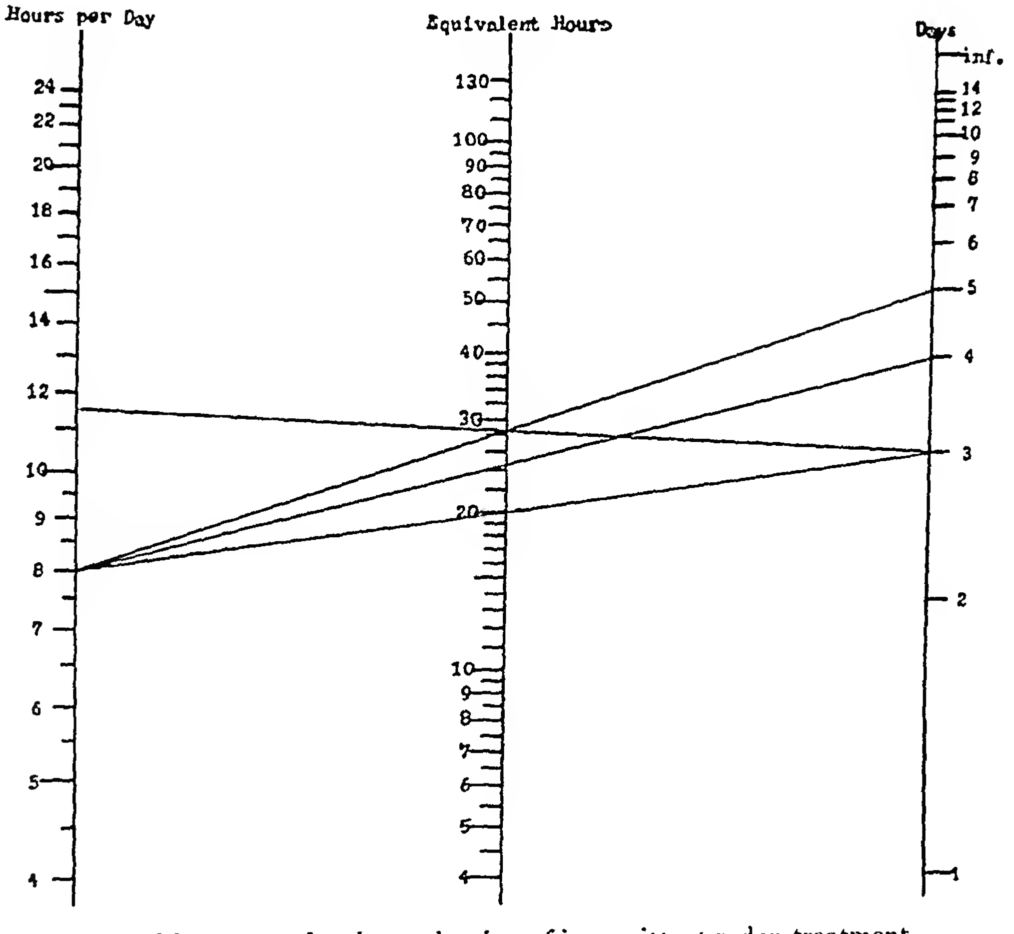

FIG. 1. Nomogram for the evaluation of intermittent radon treatment.

tained by treating 11.5 hours per day over 3 days.

Sometimes the treatment is interrupted for one day (e.g. a Sunday) and the contribution of this day must be subtracted from the equivalent hours. This is easily done as is best seen by an example. Suppose under the conditions given above the fourth day is to be omitted from treatment. The equivalent hours for 4 days are 24.5 hours and for 3 days they are 20 hours. Clearly, the contribution of the fourth day is then $24.5-20=4.5$ hours which must be subtracted from the previous value of 28.5 hours. The resulting treatment is thus equivalent to 24 hours using radium.

It must be realized that intermittent radon treatments require greatly increased amounts of radon compared with those necessary for continuous treatments and the increase may easily become prohibitive, particularly for large applicators. Nevertheless, the described nomogram has been found very useful at this Hospital.

APPENDIX

In the following, the formula is derived on which the nomogram is based. For the actual design of it, however, reference should be made to any textbook on graphical computation.

If $\mathcal{Q}_0$ is the number of millicuries of radon at the beginning of treatment then the amount remaining after a time t is given by $\mathcal{Q}=\mathcal{Q}_0\cdot e^{-\lambda t}$ (If t is stated in days the decay constant $\lambda=0.181$ days^{-1}.) The dose delivered during a time element dt is proportional to $\mathcal{Q}\cdot dt$ and the total dose is proportional to the sum of all contributions. For the first day this becomes

$$\mathcal{Q}_0\int_0^{n/24} e^{-\lambda t}dt$$

where n is the number of hours treated per day. A similar integral applies for the second day with its upper and lower limit increased by one (day), viz.:

$$\mathcal{Q}_0\int_1^{1+n/24} e^{-\lambda t}dt.$$

If treatment is carried out for N consecutive days then a sum of N such integrals is obtained. In case of radium treatment the dose does not depend on the time distribution and simply becomes proportional to $\mathcal{Q}_0\cdot T$. T is thus defined as the number of equivalent hours and becomes

$$T_{\text{hours}}=24\sum_{\nu=0}^{\nu=N-1}\int_{\nu}^{\nu+n/24} e^{-\lambda t}dt$$
$$=24\sum_{\nu=0}^{\nu=N-1}\frac{1}{\lambda}\cdot\left[e^{-\lambda\nu}-e^{-\lambda(\nu+n/24)}\right].$$

The factor 24 is necessary because λ is referred to days and T is measured in hours. Taking the constant factors in front of the sum leaves a simple geometric progression the sum of which can be worked out by elementary algebraic rules.

$$T=\frac{24(1-e^{-\lambda n/24})}{\lambda}\cdot\sum_{\nu=0}^{\nu=N-1} e^{-\lambda\nu}$$
$$=\frac{24(1-e^{-\lambda n/24})}{\lambda}\times\frac{1-e^{-\lambda N}}{1-e^{-\lambda}}=f(n)\times F(N).$$

T is thus given as product of two factors of which one depends only on n and the other only on N. Such relations are conveniently represented by an alignment chart consisting of three parallel and equidistant scales as described in the paper.

REFERENCES

1. Brodetsky, S. A First Course in Nomography. Bell, London, 1920.
2. Lipka, J. Graphical and Mechanical Computation. Wiley, New York, 1918.
3. VanVoorhis, M. G. How to Make Alignment Charts. McGraw-Hill, New York and London, 1937.

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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Twenty-eighth Annual Meeting: 1945, canceled.

EDITORIALS

NONTUBERCULOUS PULMONARY CALCIFICATION

CALCIFIED pulmonary lesions have been the source of much speculation and investigation since Sayers and Meriwether's report[1] on miliary lung disease due to an unknown cause. And now calcified pulmonary lesions assume greater and greater significance in view of the mass surveys of chests that are being made in the general population and in view of the fact that roentgen findings are often the basis for rejecting numbers of persons for the Armed Services. One of the significant problems involves the marked variation in the different parts of the country in the frequency of pulmonary calcification observed in roentgenograms of the chest. The important significance of this was recently brought out in a paper by Long and Stearns[2] based on Selective Service records in which they showed the prevalence of calcified lesions in the lung to vary from 6 per cent in Oregon to 28 per cent in Kentucky. It has been known for some time that an area of high prevalence of calcified pulmonary lesions occurs in the central half of the United States, namely, in Kentucky, Arkansas, Illinois, Indiana, Iowa, Maryland, Mississippi, Missouri, North Carolina, Ohio, Tennessee, Virginia and West Virginia, with a frequency generally lower in the states to the north, south and west of that area.

While pulmonary calcification is generally interpreted as evidence of healed tuberculosis, certain investigators have concluded that tuberculosis is by no means the only disease which brings about such lesions. Lumsden and Dearing observed a marked tendency to geographic distribution of pulmonary calcification and this was associated closely with the occurrence of limestone and chert formations.[3] Since these calcified pulmonary lesions occurred in a large proportion of persons who had negative tuberculin reactions a diligent search has been made for nontuberculous origins of the lesions.[4]

A number of investigators believe that essentially all pulmonary calcification is due to tuberculosis in spite of a negative tuberculin reaction, the assumption being that in such cases sensitivity to tuberculin has been lost with the healing of the tuberculous lesion, whereas there are those who take issue with this explanation because many of the cases occur in children and that repeated tuberculin tests in this group of cases have shown an extremely low rate of positives.

Recently Palmer[5] has had an opportunity to study the question of tuberculin negative pulmonary calcifications. This opportunity was afforded in an extensive investigation on tuberculosis in student nurses which was conducted cooperatively by the National Tuberculosis Association, the United States Public Health Service and a large number of tuberculosis specialists throughout the country.

Approximately 10,000 student nurses in sixty-five nursing schools in nine widely distributed metropolitan centers were under close observation. The study included

[1] Sayers, R. R., and Meriwether, F. V. Miliary lung disease due to unknown cause. Am. J. Roentgenol. & Rad. Therapy, 1932, *27*, 337–351.

[2] Long, E. R., and Stearns, W. H. Physical examination at induction. *Radiology*, 1943, *41*, 144–150.

[3] Editorial. Calcified pulmonary lesions. Am. J. Roentgenol. & Rad. Therapy, 1943, *49*, 823–825.

[4] Lumsden, L. L., and Dearing, W. P. Epidemiological studies of tuberculosis. *Am. J. Pub. Health*, 1940, *30*, 219–228.

[5] Palmer, C. E. Nontuberculous pulmonary calcification and sensitivity to histoplasmin. *Pub. Health Rep.*, May 11, 1945, *60*, 513–520.

a tuberculin test and 14 by 17 inch chest roentgenograms at six month intervals. The results of this study bring out clearly the geographic regional differences in the frequency of pulmonary calcification as well as the fact that, especially in states in the central eastern part of the country, the majority of nurses with calcification have negative tuberculin reactions.

During this study, attempts were made to determine the etiology of the pulmonary calcification in tuberculin negative persons, and a study of the various fungi seemed indicated, especially since some reports have stressed *Coccidioides immitis* as an important pulmonary pathogen. Intradermal tests with coccidioidin were given to a sample group included in the study of student nurses in Detroit, Kansas City, Philadelphia and Baltimore. The results were essentially negative since only a very few reactors to coccidioidin were found, and many of the nurses who reacted to this test had lived or traveled in the southwestern part of the country or in California where coccidioidomycosis is known to be endemic.

Palmer and his associates investigated the possibility that infection with *Histoplasma capsulatum* might be a cause of pulmonary calcification and a large number of nurses were given intradermal histoplasmin tests. The results of this test would indicate that infection with histoplasma is very common in widespread localities in the United States, and that it is probably the principal nontuberculous cause of pulmonary calcification. Palmer's conclusions are based on the assumption that skin sensitivity to the histoplasmin used in his study is indicative of infection with histoplasma.

Meleny, some time ago, expressed his belief that histoplasmosis is not as infrequent as might be supposed, that its infrequency is assumed because it is rarely diagnosed, that the organism is widely distributed throughout the world, and that it would undoubtedly be recognized with increasing frequency in the future as a cause of hitherto unexplained illnesses.[6]

In order to insure uniformity in the interpretation of findings in the study conducted by Palmer, all skin tests were performed and read by one person and all roentgenograms of the chest were interpreted by one experienced roentgenologist. The roentgen findings in this particular study on nontuberculous pulmonary calcification were limited to a report as to the presence or absence of shadows characteristic of calcification in the lung parenchyma or lymph nodes. The roentgen findings were interpreted and recorded without knowledge of the tuberculin reaction and prior to the testing with histoplasmin.

Palmer thinks it is clear from the data collected that there are wide geographic differences in the frequency of the reactions to histoplasmin. Among the group of nurses who had lived essentially all their lives in Minnesota less than 5 per cent showed any reaction to histoplasmin, while in Missouri more than 60 per cent were sensitive. He believes that this geographic distribution may be interpreted as evidence that the histoplasmin reaction is specific indication of some previous experience of the individual, presumably infectious, since it would be difficult to account for such a variation if the reaction were nonspecific. In addition, the consistent high degree of correlation of the histoplasmin reaction with pulmonary calcification in the various localities is similar indirect evidence of its specificity and of its medical significance.

It is known that infection with histoplasma may produce a fatal disease in recognized cases. Since numerous immunological cross reactions are known to exist among bacteria, it seems best in the present state of our knowledge to interpret the histoplasmin reaction as evidence of previous infection with *Histoplasma capsulatum* or an immunologically related organism.

Palmer states that if the interpretation of the specificity of the histoplasmin test is correct, a number of important implica-

[6] Editorial. Histoplasmosis. Am. J. Roentgenol. & Rad. Therapy, 1945, [illegible]

tions at once become apparent. First, histoplasmosis, in the mild, perhaps subclinical form, may be a common infection, at least in the states in the central eastern half of the country. The number of persons so affected in this area may total many millions. The epidemiological evidence indicates that a high proportion of the pulmonary calcification observed in individuals living in this group of states may be due to an infection with histoplasma or a related organism and not to tuberculosis. If this assumption proves to be correct, a number of problems in the study of tuberculosis may be clarified.

Thus, Palmer, in his study of a large group of nurses in widely separated states, has pointed out a possible further cause of pulmonary calcification which has until recently been attributed to tuberculosis. Further studies are awaited to confirm or disprove Palmer's interesting observation.

VERNOR M. MOORE
1886–1944

Dr. Vernor M. Moore, a member of the American Roentgen Ray Society since 1925, died at his home in Grand Rapids, Michigan, December 30, 1944, after a sudden and short illness.

Born at Freeport, Michigan, February 10, 1886, he obtained his pre-medical training at Olivet College and graduated from the Medical School of the University of Michigan with the class of 1911. Following two years of general practice he became associated with the late Dr. Richard R. Smith. In 1916 Dr. Moore opened his office for the private practice of radiology in the

Metz Building where he continued his practice until his death.

Dr. Moore was greatly interested and took a very active and prominent part in the work of organized medicine. He acted as Councilor for ten years, one year as chairman of the Executive Committee of the Council and at the time of his death was President-elect of the Michigan State Medical Society.

Early in his medical career, Dr. Moore became very much interested in chest pathology. He was a member of the Board of Directors of the Kent County Anti-tuberculosis Society. He was held in high regard for his ability as a radiation therapist.

Dr. Moore was a Past President of the Kent County Medical Society and the Michigan Association of Roentgenologists. He held membership in the Radiological Society of North America and was a diplomate of the American Board of Radiology.

A sincere and loyal friend, never too busy to assist those starting in the practice of medicine, Dr. Moore will be greatly missed by his many friends and colleagues.

Leland E. Holly

RALPH EMERSON MYERS
1888–1945

DR. RALPH EMERSON MYERS was born on January 28, 1888, at Buskirk, New York, the son of Dr. Adam Y. and Mary E. Myers. He obtained his early training at private school and the Hoosick Falls High School, from which he was graduated in 1904. After an additional year's work, he entered Wesleyan University, Middletown, Connecticut, in the fall of 1905 and became engrossed in the study of Greek and Latin. In 1907 he transferred to Yale University and received his B.A. from there in 1909 with honors and election to Phi Beta Kappa and Sigma Xi. At Yale

he turned his attention from the classics to science and mathematics, becoming interested in physiological chemistry under the stimulating teaching of the late Professor Lafayette B. Mendel. He spent an additional year's work in this field and received an M.A. from Yale in 1910. Deciding to try his hand at the practical side of biochemistry he became chief chemist at the Battle Creek Sanitarium. After less than a year he resigned this position to accept an Austin Teaching Fellowship in Physiology at the Harvard Medical School under Professor Walter B. Cannon. He remained there until the fall of 1912, when he accepted an appointment at the Albany Medical College (Union University) as lecturer in pharmacology and physiology. The following year he was promoted to an adjunct professorship in these subjects.

At this point in his career he was intensely interested in pharmacology and, believing that the German text, Gottlieb and Meyer, gave the best presentation of the subject, he prepared a translation for his own students. He was planning to go to Vienna to work in pharmacology with Professor Hans Horst Meyer when the first world war caused a change in his plans. He then decided without further delay to complete work for a medical degree and entered Cornell University Medical College, New York, in the fall of 1914. A considerable number of medical subjects had already been taken at Yale and Harvard, so that scarcely three years were required to complete the required course. The fourth year was occupied with an internship at the Memorial Hospital. While an intern he spent considerable time in administering radium for Dr. H. H. Janeway at Memorial Hospital and this doubtless materially influenced his subsequent career in radiology. Upon receiving his M.D. in 1918 he was commissioned a First Lieutenant in the Medical Corps of the United States Army and served until the fall of 1919. On his discharge from the Army he was appointed professor of pharmacology at the University of Maryland School of Medicine. He resigned at the end of the year (1920) to accept the professorship of pharmacology and physiological chemistry at the George Washington University School of Medicine. In the spring of 1922 he was offered and accepted the directorship of laboratories at St. Anthony's Hospital, Oklahoma City. Realizing his lack of special training in pathology, he spent the summer at Memorial Hospital in New York with Dr. James Ewing. Dr. Ewing's intense interest in cancer and its treatment must have unconsciously further stimulated his interest in radium and roentgen therapy of malignant tumors. Upon his arrival at St. Anthony's Hospital in Oklahoma City to assume the directorship of laboratories he found that the Department of Radiology was nominally under his charge, necessitating his giving more attention in this direction than he had anticipated, with the result that he soon found himself intensely interested in radiology. In 1929 after having held the post of director of laboratories for seven years he resigned in order that he might devote his entire time to radiology, in which field he gained wide recognition.

In addition to membership in the American Radium Society, he was a fellow of the American College of Radiology, held a certificate from the American Board of Radiology, and was a member of the Radiological Society of North America, the American Medical Association and the American Association for the Advancement of Science. He served as Secretary and later as Chairman of the Section on Radiology of the Southern Medical Association. He died on March 14, 1945 from meningitis due to type III pneumococcus after an illness of two days. A wife, Lucy, whom he married in 1919, and a brother, Victor, survive.

Victor C. Myers

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

UNITED STATES OF AMERICA

AMERICAN ROENTGEN RAY SOCIETY
Secretary, Dr. H. Dabney Kerr, University Hospital, Iowa City, Iowa. Annual meeting: 1945, canceled.

AMERICAN COLLEGE OF RADIOLOGY
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago.

SECTION ON RADIOLOGY, AMERICAN MEDICAL ASSOCIATION
Secretary, Dr. U. V. Portmann, Cleveland Clinic, Cleveland, Ohio. Annual meeting: 1945, canceled.

ARKANSAS RADIOLOGICAL SOCIETY
Secretary, Dr. J. S. Wilson, Mack Wilson Hospital, Monticello, Ark. Meets every three months and also at time and place of State Medical Association.

RADIOLOGICAL SOCIETY OF NORTH AMERICA
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: 1945, to be announced.

RADIOLOGICAL SECTION, BALTIMORE MEDICAL SOCIETY
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

SECTION ON RADIOLOGY, CALIFORNIA MEDICAL ASSOCIATION
Secretary, Dr. Earl R. Miller, University of California Hospital, San Francisco, Calif.

RADIOLOGICAL SECTION, CONNECTICUT MEDICAL SOCIETY
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets bimonthly on second Thursday, at place selected by Secretary. Annual meeting in May.

SECTION ON RADIOLOGY, ILLINOIS STATE MEDICAL SOCIETY
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

RADIOLOGICAL SECTION, LOS ANGELES COUNTY MEDICAL ASSOCIATION
Secretary, Dr. Roy W. Johnson, 1407 S. Hope St., Los Angeles, Calif. Meets on second Wednesday of each month at the County Society Building.

RADIOLOGICAL SECTION, SOUTHERN MEDICAL ASSOCIATION
Secretary, Dr. Roy G. Giles, Temple, Texas.

BROOKLYN ROENTGEN RAY SOCIETY
Secretary, Dr. Leo Harrington, [illegible] Ocean Ave., Brooklyn, N.Y. Meets monthly on fourth Tuesday, [illegible] to April.

BUFFALO RADIOLOGICAL SOCIETY
Secretary, Dr. Joseph S. Gian-Franceschi, [illegible] Niagara St., Buffalo, N. Y. [illegible]

CHICAGO ROENTGEN SOCIETY
Secretary, Dr. [illegible]

[illegible]

DETROIT ROENTGEN RAY AND RADIUM SOCIETY
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

FLORIDA RADIOLOGICAL SOCIETY
Acting Secretary, Dr. Walter A. West, [illegible] Bldg., Orlando, Fla. Meetings in May and November.

GEORGIA RADIOLOGICAL SOCIETY
Secretary, Dr. James J. Clark, 478 Peachtree St., Atlanta, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

RADIOLOGICAL SOCIETY OF KANSAS CITY
Secretary, Dr. Arthur B. Smith, [illegible] Bldg., Kansas City, Mo. Meets third Thursday of each month.

ILLINOIS RADIOLOGICAL SOCIETY
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meets three times a year.

INDIANA ROENTGEN SOCIETY
Secretary, Dr. H. C. Ochsner, Methodist Hospital, Indianapolis. [illegible]

IOWA X-RAY CLUB
Secretary, Dr. Arthur W. Erskine, [illegible] Cedar Rapids, Iowa. [illegible] during annual [illegible] Iowa State [illegible] Special meetings [illegible]

KENTUCKY RADIOLOGICAL SOCIETY
Secretary, Dr. W. C. Martin, [illegible] Louisville. [illegible]

LONG ISLAND RADIOLOGICAL SOCIETY
Secretary, Dr. [illegible] N. Y. [illegible]

LOUISIANA RADIOLOGICAL SOCIETY
Secretary, Dr. J. R. [illegible] Shreveport. [illegible]

[illegible]

* [illegible]

nual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

North Dakota Radiological Society
Secretary, Dr. L. A. Nash, St. John's Hospital, Fargo. Meetings held by announcement.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

Ohio Radiological Society
Secretary, Dr. Henry Snow, 1061 Reibold Bldg., Dayton, Ohio. Meets during annual meeting of Ohio State Medical Association.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport.

Philadelphia Roentgen Ray Society
Secretary, Dr. C. L. Stewart, Jefferson Hospital, Meetings first Thursday of each month, October to May, at at 8:00 p.m., in Thomson Hall, College of Physicians, 21 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. L. M. J. Freedman, 4800 Friendship Ave. Meets 6:30 p.m. at The Ruskin on second Wednesday, each month, October to May inclusive.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Murray P. George, Strong Memorial Hospital. Meets monthly on third Monday from October to May, inclusive, 8 p.m. at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary Dr. A.M. Popma, 220 N. First St., Boise, Idaho.

St. Louis Society of Radiologists
Secretary, Dr. Edwin C. Ernst, Beaumont Medical Building, St. Louis, Mo. Meets fourth Wednesday of each month, except June, July, August, and September, at a place designated by the president.

San Diego Roentgen Society
Secretary, Dr. Henry L. Jaffe, Naval Hospital, Balboa Park, San Diego, Calif. Meets monthly on first Wednesday at dinner.

San Francisco Radiological Society
Secretary, Dr. Carlton L. Ould, University of California Hospital, San Francisco 22. Meets monthly on the third Thursday at 7:45 p.m., first six months of the year at Lane Hall, Stanford University Hospital, and second six months at Toland Hall, University of California Hospital.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 p.m., September to May inclusive.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, 707 Walnut St., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. Asa E. Seeds, Baylor Hospital, Dallas, Texas. Next annual meeting, Temple, Texas, Jan. 17, 1945.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 p.m. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 p.m., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. E. L. Flanagan, 116 E. Franklin St., Richmond, Va. Meets annually in October.

Washington State Radiological Society
Secretary. Dr. Thomas Carlile, 1115 Terry St., Seattle. Meets fourth Monday each month, October through May, College Club, Seattle.

X-ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly, third Thursday evening.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Medical Members' meeting held monthly on third Friday at 2:30 p.m. and Ordinary Meeting at same time on following Saturday, October to May, 32 Welbeck St., London, W.1.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month at 4:45 p.m. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. J. W. McKay, 1620 Cedar Ave., Montreal, P. Q.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

South America

Sociedad Argentina de Radiologia
Secretary, Dr. Guido Gotta, Buenos Aires, Argentina. Meetings are held monthly.

Sociedad Peruana de Radiologia
Secretary, Dr. Victor Giannoni, Apartado, 2306, Lima, Peru. Meetings held monthly except during January, February and March, at the Asociación Médica Peruana "Daniel A. Carrión, Villalta, 218, Lima.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse Biel. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad: USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 p.m.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

PENNSYLVANIA RADIOLOGICAL SOCIETY

The Thirtieth Annual Meeting of the Pennsylvania Radiological Society was held at the William Penn Hotel, Pittsburgh, Pennsylvania, on May 5 and 6, 1945. On Saturday, May 5, the following scientific program was presented:

Management of Fractures. John R. Moore and W. E. Chamberlain, Philadelphia, Pa.

Odds and Ends. John M. Keichline, Huntingdon, Pa.

Roentgenographic Diagnostic Experiences in a Small General Hospital. John H. Harris, Harrisburg, Pa.

Wilms' Tumor. William J. Corcoran, Scranton, Pa.

An Unusual Abdominal Tumor. F. N. Hoffmeier, Hagerstown, Md.

Injuries about the Elbow Joint. George W. Chamberlain, Reading, Pa.

Experiences in the Treatment of Tinea Capitis. Lester M. J. Freedman, Pittsburgh, Pa.

Heart Size in Infants and Children. Sidney J. Hawley, Danville, Pa.

Intestinal Polyposis. Leslie H. Osmond, Pittsburgh, Pa.

The meeting on Sunday, May 6, was given over to a discussion of "Interesting Diagnostic and Treatment Cases," with Sidney J. Hawley, Danville, Pa., as Chairman.

PHILADELPHIA ROENTGEN RAY SOCIETY

At the recent meeting of the Philadelphia Roentgen Ray Society the following officers were elected: *President*, Dr. Paul C. Swenson; *Vice-President*, Dr. Louis Edeiken; *Secretary*, Dr. Calvin L. Stewart; *Treasurer*, Dr. David A. Sampson.

PITTSBURGH ROENTGEN SOCIETY

At the recent meeting of the Pittsburgh Roentgen Society the following officers were elected for the ensuing year: *President*, Dr. Reuben G. Alley, Pittsburgh; *Vice-President*, Dr. Paul Meader, Pittsburgh; *Secretary-Treasurer*, Dr. Lester M. J. Freedman, Pittsburgh.

NEW ENGLAND ROENTGEN RAY SOCIETY

At its meeting on May 18, 1945, the New England Roentgen Ray Society paid honor to its distinguished member, Dr. George W. Holmes, pioneer radiologist and teacher, by establishing an annual lecture to be known as the George W. Holmes Annual Lecture.

The following officers were elected: *President*, Dr. Philip Batchelder; *Vice-President*, Dr. Robert G. Vance; *Secretary*, Dr. George Levene.

RADIOLOGICAL SOCIETY OF NEW JERSEY

At the annual meeting of the Radiological Society of New Jersey held on May 16 1945, the following officers were elected: *President*, Dr. H. J. Perlberg, Jersey City, N. J.; *Vice-President*, Dr. John Olpp, Englewood, N. J.; *Secretary*, Dr. H. R. Brindle, Asbury Park, N. J.; *Treasurer*, Dr. W. H. Seward, Orange, N. J.

CANCER TEACHING DAY

A Cancer Teaching Day was held at Binghamton, New York, on Wednesday, June 6, 1945, under the auspices of various medical societies. The following papers were presented at the afternoon session: "Treatment of Cancer of the Cervix" by Howard C. Taylor, Jr., M.D.; "Cancer of the Stomach" by George T. Pack, M.D. Following a dinner, these papers were presented at the evening meeting: "Malignancies of the Genitourinary Tract" by Ernest M. Watson, M.D.; "Cancer of the Breast" by Norman Treves, M.D.

COLONEL ALFRED A. DE LORIMIER RECEIVES ARMY AWARD

The following citation appearing among the Army Awards and Commendations in the *Journal of the American Medical Association* for May 5, 1945, Vol. 128, page 35, will be of interest to all readers of the Journal. Colonel de Lorimier is a well

known radiologist and is a member of the American Roentgen Ray Society:

Col. Alfred A. de Lorimier, formerly of Washington, D. C., was recently awarded the Legion of Merit for "service as director of the Department of Roentgenology, Army Medical School, Army Medical Center, Washington, D. C., from Sept. 8, 1939 to Oct. 1, 1942. He developed an easily transportable, complete and efficient field x-ray equipment for the Army which permits the location of bullets and shell fragments in the body of a wounded man and makes it possible for the surgeon to extract them. He tested all types of roentgenologic materials procured for the Army and formulated the specifications necessary for their purchase. He made extensive studies of the use of photoroentgenography and was instrumental in developing stereoroentgenography, which has a valuable use in induction centers and in mass surveys. By his initiative, original thinking and development work he has performed outstanding service and contributed materially to the war effort." Dr. de Lorimier graduated from the University of California Medical School, San Francisco, in 1927 and entered the service May 10, 1929.

AMERICAN BOARD OF RADIOLOGY

The examination of the American Board of Radiology originally scheduled for New York in June was canceled. The next examination will be held in Chicago some time in the fall of this year. Due notice will be sent out as soon as the time and place have been decided upon.

B. R. Kirklin, *Secretary*

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ROENTGEN DIAGNOSIS

GYNECOLOGY AND OBSTETRICS

McSweeney, Daniel J., and Moloney, Albert M. Combined x-ray and external pelvimetry. *Am. J. Obst. & Gynec.*, July, 1943, *46*, 102–109.

The authors set down the following criteria as determining the need for roentgen examination:

1. Primiparas with floating heads at term.
2. Multiparas with a history of previous difficult deliveries.
3. Primiparous breeches with apparently small pelves by external measurements (an external conjugate of less than 18.5 cm.).
4. Cases with narrow subpubic arches and outlets (a subpubic measurement of less than 6 cm.; intertuberous measurement less than 9.0 cm.; sum of intertuberous and posterior sagittal measurements of less than 15.0 cm.).
5. Elderly primiparas with an external conjugate of 18.5 cm. or less.

The roentgen examination consists of:

1. A roentgenogram directly through the pelvic inlet.
2. A true lateral view on which is measured the conjugate vera, the anterior-sagittal, posterior sagittal, the anteroposterior diameter of the mid-pelvis, the pubotuberous diameter and the biparietal diameter of the fetal head.

Assuming the fetal head to be average size, the question of probable dystocia at the various planes can be reduced to the following simple observations.

1. Dystocia at the Inlet—Measurements
   Conjugate vera under 10 cm. in generally contracted pelvis
   Conjugate vera under 9.5 cm. in flat pelvis
   Contour
   Angulation of forepelvis
   Flattened posterior pelvis
2. Dystocia at Mid-pelvis—Measurements
   Posterior sagittal under 3.5 cm.
   Subpubic arch under 5.5 cm.
   Contour
   Converging sacrum and pubis
   Sacrococcygeal platform
3. Dystocia at Outlet—Measurements
   Interpubic under 5.5 cm.
   Intertuberous under 9.0 cm.
   Pubotuberous over 11.0 cm.
   Contour
   Acute rather than obtuse arch.—*Mary Frances Vastine.*

Thoms, Herbert. The relation of the sacral promontory to the pelvic inlet. *Am. J. Obst. & Gynec.*, July, 1943, *46*, 110–116.

In this investigation the roentgenologic findings in 200 primigravid women have been studied. Because of the wide variation in position of the sacral promontory in its relation to the bony pelvic canal, some modern investigators have found that for clinical purposes it is necessary to abandon the idea that the superior strait, as described in anatomic texts, should be considered as the plane of the obstetric pelvic inlet. Thus, the position of the forward edge of the sacral promontory is too unreliable to be considered as the posterior end of the true conjugate diameter. From an obstetric point of view the plane of the pelvic inlet is considered to be bounded anteriorly by the upper posterior surface of the pubic symphysis and forward position of the iliopectineal lines, laterally by the iliopectineal lines and posteriorly by the posterior portions of these lines and the anterior upper surface of the sacrum at the point where convergence of these lines takes place. It seems that the diagonal conjugate cannot be considered as a reliable index to the true conjugate and that in some cases information so obtained may be misleading.

In the series studied, an atter
to find out if high positions of th
were associated with any par
grouping according to the divisio
pellic, mesatipellic, brachypelli
pellic types. From the analysis it
that no definite conclusions may
that the high promontory positio
if but slightly, associated with th
and mesatipellic types of pelvis.

Also in the present series, the reliability of the diagonal conjugate diameter as an index of the true conjugate diameter was determined. For this purpose 1.5 cm. was deducted from the diagonal conjugate and a leeway of 0.25 cm. plus or minus was allowed for the true conjugate. The result showed that the diagonal conjugate could be used as a satisfactory criterion in 76 instances, or *but 38 per cent of the cases.—Mary Frances Vastine.*

KANTOR, HERMAN I. Parasitic ovarian cysts. *Am. J. Obst. & Gynec.*, Sept., 1943, *46*, 412–417.

Morgagni is reputed to have described parasitic ovarian tumors as early as 1748. However, today, they are rather unusual, undoubtedly because operation is performed earlier for symptoms suggesting torsion of an ovarian tumor. Among the ovarian parasitic tumors, the type most frequently seen is the dermoid.

The development of parasitic tumors may be divided arbitrarily into four stages:

First Stage. Reduction in blood supply due to slow torsion of the mass on its pedicle.

Second Stage. Adhesions formed between the mass and adjacent tissues of the omentum.

Third Stage. Additional torsion and further decrease in the primary blood supply.

Fourth Stage. Additional torsion to the point of complete amputation of the pedicle.

A case is reported in which the patient's complaint was "attacks of pain localized to the right quadrant." The roentgenologist reported, ". . . several clusters of calcification within the pelvis, one having the typical appearance of a calcified fibroid. Below this fibroid is another circular calcification which may be an additional fibroid." At operation the right ovary was found to be converted into a multilocular dermoid cyst attached by two pedicles, one communicating with the infundibulopelvic ligament and the other with the peritoneum. Both of these pedicles were twisted. Another cyst was found posterior to the uterus. This was attached completely to the omentum by a pedicle.—*Mary Frances Vastine.*

HUNTER, ROBERT M. An attempt to correlate the pre-eclamptic state with a congenital anomaly of the kidney. *Am. J. Obst. & Gynec.*, July, 1943, *46*, 91–96.

This study from the department of obstetrics at Hahnemann Medical College and Hospital is based on 74 cases divided into three groups:

1. Twenty-two patients with pre-eclampsia.
2. Twenty-five cases of uropathies complicating pregnancy.
3. Twenty-seven normal pregnant women near term.

Routine intravenous urograms were made in all 74 cases. The roentgenograms were read by a member of the roentgen department who was intentionally deprived of any knowledge of the clinical status of the patients. He was asked to state whether the kidney pelves were intrarenal or extrarenal. After all roentgenograms were read, the clinical status was correlated with the roentgenologic status. The following results were obtained: (1) of the 22 toxic cases, 20 patients had intrarenal pelves and 2, extrarenal pelves. (2) Of the 25 patients with uropathic conditions complicating pregnancy who did not have toxemia at the time the urograms were taken, 17 had extrarenal pelves, and 8, intrarenal pelves. (3) In the normal control group, totaling 27 cases, there were 18 with extrarenal pelves and 9 with intrarenal pelves.

The author concludes that an intrarenal pelvis is more common in the pre-eclamptic state than in normal pregnancy, or even in patients with uropathic conditions complicating pregnancy. He suggests that since normally the kidney pelvis is dilated in pregnancy, in the presence of an intrarenal kidney pelvis the resulting increased intrarenal pressure must of necessity cause back pressure in the kidney tubule. This, in turn, must be compensated for by an increase in glomerular pressure or, in other words, an increase in blood pressure.—*Mary Frances Vastine.*

THOMAS, SYDNEY. Diffuse calcification of the placenta demonstrable in vivo. *Radiology*, Dec., 1943, *41*, 573–575.

Calcification occurs normally in the placenta and should not lead to a diagnosis of disease. The amount of calcium depends on the length of the pregnancy and the mother's calcium metabolism. Such calcifications are generally not demonstrable during life because they are small and spread over a wide area and the fetus is often moving or the uterus contracting and motion is transmitted to the calcified areas by these movements or those of the uterine or aortic vessels. They will probably be seen more frequently since the introduction of the rotating

anode tube and with the use of improved technique.

A case is described in a white primipara nineteen years of age who came for examination at the end of the tenth month of pregnancy on account of hemorrhage. The possibility of placenta previa was considered and roentgenograms made for the purpose of localizing the placenta. The lateral view of the abdomen showed many opacities in the shadow of the placenta. The patient was delivered of a normal female infant ten and a half months after the estimated beginning of the pregnancy. The reticular pattern of the calcifications should always be looked for in suspected placenta previa. —*Audrey G. Morgan.*

SKELETAL SYSTEM

Mock, Harry E. Symposium on injuries of the head, chest, and back; head injuries. *Radiology*, Dec., 1943, *41*, 527–531.

The author is a general surgeon who has made a hobby of collecting cases of fracture of the skull. He has records of a little more than 7,000 cases, 500 of which he has treated himself. He has made two surveys of a large number of hospitals and finds that in the second survey the mortality rate has declined 7 per cent. His own mortality rate ten to twelve years ago was 20–21 per cent, but he has now reduced it to 16 per cent.

He outlines the proper course of treatment and points out factors that cause death. Much depends on careful and close observation of the patient, with blood pressure, pulse, respiration and temperature recorded every two hours and sometimes as often as every half hour. Every case of head injury should have a roentgen examination but not while the patient is in shock, coma or wild delirium. The taking of roentgenograms in the first few hours increases mortality.

He classifies the hospitals examined as having good, average and poor management. In the first group the average mortality was 19 per cent, in the second 25 per cent and in the third 38 per cent. The lowest mortality in any one hospital was 17 per cent and the highest 42 per cent. The cases were of the same type and same average degree of severity. The differences were due to differences in attention to detail.

He cites as pathological causes of death which occur in 10–12 per cent of cases and cannot be prevented: cerebral shock, massive brain lesions, hemorrhages in vital centers, serious associated injuries and complicating diseases. Other causes due to mismanagement and therefore preventable occur in 5 to 15 per cent of cases. They are: failure to treat shock first, failure to observe and chart the course of the injury, a hit or miss type of dehydration, overdehydration and starvation, too few or too late spinal punctures, too few, too many or too early operations and oversedation.—*Audrey G. Morgan.*

Kenning, J. C., and Harris, Ivor D. Some considerations concerning the diagnosis of skull fractures. *Radiology*, Dec., 1943, *41*, 532–538.

Over 50,000 cases of injury of the skull have been given roentgen examination at the Detroit Receiving Hospital in the past eighteen years and about 9,000 of these have shown fractures. In all such cases right and left lateral, frontal and occipital views are taken. Care in technique and the use of the smallest possible focal spot and of the Potter-Bucky diaphragm are important. If there is a questionable line or if a fracture indicated clinically is not found, further roentgenograms are taken showing the suspected area in the greatest detail and with the least possible superimposition.

It has been found that 26.8 per cent of all fractures occur in the anterior third of the skull, 45.3 per cent in the middle third and 27.9 per cent in the posterior third. Linear fractures must be differentiated from suture lines, diploic markings, vascular grooves and artifacts. Roentgenograms illustrating these differentiations and the different types of skull fracture are given.

In fractures of the anterior third the cribriform plate of the ethmoid may be involved, resulting in leakage of cerebrospinal fluid and danger of meningitis and abscess. Involvement of the anterior wall of the frontal sinus is less dangerous than that of the posterior wall. It may be necessary to take roentgenograms at a tangent in order to differentiate between fractures of the anterior and posterior walls. If there is impairment of vision, special orbital views should be taken.

Fractures in the middle area or mastoid region are more dangerous than in the other regions and at the same time more easily overlooked. The mortality increases with increasing involvement of the mastoid. There are few complicating features in fractures of the posterior third or occipital region.

Fractures of the mastoid generally show bony non-union. The time required for union has become more important medicolegally since automobiles have come into use and will be even more so after this motorized war. It has been claimed that a fresh linear fracture can be differentiated from an old one after eight months but this is not always true of fractures of the mastoid and of the base of the skull.—*Audrey G. Morgan.*

Merrifield, Frederick W. The management of jaw fractures. *Radiology*, Dec., 1943, *41*, 539–542.

The mandible is the most frequently fractured of the facial bones. The fractures may be partial or complete and they occur most frequently at the angle or at the mental foramen. Fractures are apt to occur at sites of anatomic weakness, for instance in children with unerupted teeth in the cuspid region.

Diagnosis can generally be made from the history of injury and the characteristic appearance. The extent of the injury can be determined by roentgen examination. The entire mandible from one side to the other should be examined.

Treatment consists of care of the soft parts to prevent or minimize infection and reduction of the fragments, which generally brings about restoration of occlusion of the teeth. The teeth act as landmarks for successful reduction and the fragments may be fixed by wiring the teeth. It may be possible to retain teeth even if there is some infection. The mandible heals even when there is severe osteomyelitis if adequate drainage is maintained. Splints are useful in some cases, particularly if there is loss of bone.

The reduction and fixation of fractures of the maxilla and facial bones are also discussed. Diet is an important consideration in the treatment of fractures of the jaws. It should be nourishing and of sufficient vitamin content, and capable of passing through a feeding tube by easy suction. Sometimes nasal feeding must be used. The caloric requirement is from 2000 to 3000.—*Audrey G. Morgan.*

Bennett, J. Paul. The roentgenologic diagnosis of chest injuries. *Radiology*, Dec., 1943, *41*, 543–550.

In an introduction to this paper Dr. Mock points out that the association of chest injuries with injuries of the skull enormously increases the mortality of the latter. Chest injuries, always serious, are particularly so when associated with injuries of the brain.

The author discusses the different types of injuries of the chest. In studying the ribs a number of views must be taken, as a fracture may not show if the beam is tangential to the curve of the affected rib. A fracture of cartilage may not show on the roentgenogram unless the cartilage is ossified. Lateral or oblique views are necessary to demonstrate fractures of the sternum. In studying the routine chest roentgenogram the bones should always be observed. Fractures of the ribs or even a fractured dorsal vertebra may be seen. Varying degrees of emphysema may be seen on the roentgenogram, which may be the only evidence of a perforated lung. Pneumothorax may be present, with or without fracture of the ribs. It may be so slight that roentgenograms in both inspiration and expiration are necessary to detect it.

Hemorrhage into the pleural cavity may result from trauma. Blood cannot be distinguished from any other fluid on the roentgenogram. Sometimes on the posteroanterior view encapsulated fluid may simulate pneumonic consolidation, while on the lateral view it shows clearly. Hemorrhage into the lung parenchyma may simulate pneumonia, tuberculosis or other infections. The mediastinal structures may be injured in trauma. Severe damage to the great vessels usually causes almost immediate death but if the patient survives, the mediastinal shadow is broadened and shows straight vertical borders. A blow over the precordium may cause hemorrhage into the pericardium and the roentgenogram shows pericardial fluid. Air is occasionally seen in the pericardium as a clear area between the pericardium and the outline of the heart. Foreign bodies are occasionally seen in the heart muscle or in the chambers. A case is described in which a large piece of glass was not seen on the roentgenogram taken during life but was seen on that of the extirpated heart.

Penetration of the diaphragm may cause subdiaphragmatic hemorrhage and subsequent abscess. Trauma of the diaphragm may result in herniation. The hernia may be confused with eventration of the diaphragm. A left-sided eventration displaces the heart to the right, while a posterior hernia will not. But an anterior hernia may cause such a displacement.

Pneumoperitoneum may be of value in differentiation.

Cases of the different forms of chest injury are described and illustrated with roentgenograms.—*Audrey G. Morgan.*

Mock, Harry E. Back injuries: introduction. *Radiology*, Dec., 1943, *41*, 551–553.

The author calls attention to the great prevalence of low back pain and the many changes there have been in its diagnosis and treatment. These patients generally come to the surgeon and want a definite diagnosis. It is true that there are cases that are definitely surgical and require the removal of a cord tumor, an osteoma or a protruding disc. But often even after a protruding disc has been removed the back pain persists, and often even the removal of foci of infection has not cured the pain. There are other factors—psychogenic, constitutional and postural—which must be taken into consideration. Roentgen examination should be made but the whole responsibility should not be thrown on the roentgenologist. The surgeon should make a thorough physical examination of the patient and not accept slight spinal changes found by the roentgenologist as being necessarily the cause of the pain. Correction of faulty posture and living conditions and the resoration of muscle balance may do much more for the patient than surgery.—*Audrey G. Morgan.*

Carey, Eben J. Anatomical and physiological considerations prerequisites to diagnosis of back trauma. *Radiology*, Dec., 1943, *41*, 554–559.

This thorough review of the anatomy and physiology of the spinal column is given because of the importance of such knowledge in the diagnosis and treatment of low back pain. There are a number of anomalies of the spine that are found in patients who are free of symptoms but their spines are less stable than normal and more prone to strain and injury. They are: (1) elongation of the transverse process of the fifth lumbar vertebra which is found in 25 per cent of the cases of low back pain. This process impinges on the ilium and friction causes a painful bursa; (2) sacralization of the fifth lumbar vertebra. This is found in about 3.5 per cent of normal persons and about half of these have low back pain; (3) defect of the neural arch (spina bifida occulta). This is found in about 5 per cent of spines examined roentgenologically. It renders the spine weak and liable to injury; (4) variations in the spinous processes; (5) variations in the lumbosacral angle; (6) variations in the joint surfaces; (7) spondylolisthesis; (8) constitutional variations. Long thin individuals are apt to suffer sacroiliac sprain while short heavy ones are apt to have lumbosacral sprain.—*Audrey G. Morgan.*

Morton, S. A. The differential diagnosis of traumatic lesions of the spine. *Radiology*, Dec., 1943, *41*, 560–564.

It is often hard to differentiate traumatic from non-traumatic lesions of the spine on the roentgenogram. Fractures and dislocations are of course easily diagnosed but there are other changes apparently due to trauma which are non-traumatic in origin. One of these is non-traumatic dislocation of the atlanto-axial joint, usually seen in young people in association with infections of the throat or of the cervical lymph nodes. Laminagrams are often of value in the diagnosis of this condition. A basal view of the skull is recommended in order to show the relation between the atlas and the axis.

Persons who have had injuries of the neck may complain of pain in the neck and down one or both arms. Roentgenograms in these cases may show spurs projecting posteriorly from the bodies of the cervical vertebrae.

In the dorsal region there are two more non-traumatic conditions that may be mistaken for traumatic ones—collapse of the body of a vertebra from osteoporosis and those changes in the epiphyses of the body of a vertebra commonly called persistent epiphysis. They are really corners of the body of the vertebra pulled off by the action of muscles or ligaments.

Near the lumbosacral junction a congenital defect of the isthmus may be mistaken for a traumatic lesion.

Hypertrophic lesions are questionable. They may be seen in the spines of sedentary persons who have not suffered trauma and they may be absent in the cases of trauma. There is little or no connection between the degree of an injury and the subsequent development of hypertrophic spurs. So there are many cases in which the roentgenologist must be extremely cautious in expressing a dogmatic opinion as to whether a lesion of the spine is traumatic or non-traumatic.—*Audrey G. Morgan.*

LAPIDUS, PAUL W., GUIDOTTI, FRANK P., and COLETTI, C. J. Triphalangeal thumb; report of six cases. *Surg., Gynec. & Obst.*, Aug., 1943, *77*, 178–186.

This article is summarized by the authors as follows:

1. Six cases of triphalangeal thumb have been reported. In 3 of these heredity of the anomaly could be established.

2. This anomaly must be considered rare since the first 3 cases were noted among more than 75,000 draftees examined.

3. None of the various theories advanced at present can be accepted as an adequate explanation for the cause of this anomaly.

4. From a review of the recorded cases, including the 6 cases reported here, it appears that triphalangism of the thumb may have at least two origins: (*a*) double index or an extra finger fused on the radial side of the hand which lost its thumb, simulating the triphalangeal thumb, (*b*) remnant of one of the phalanges of an incompletely developed bifid thumb, simulating a third phalanx.

5. If these two theories are correct, it follows therefore that in the first the triphalangeal digit is not a true thumb. According to the second theory, the additional phalanx is not a true middle phalanx similar to that of the lesser fingers, but a remnant of the base of one of the phalanges of a bifid thumb. The latter theory is favored by the authors.—*Mary Frances Vastine.*

JONES, DEAN B. March fracture of the inferior pubic ramus. *Radiology*, Dec., 1943, *41*, 586–588.

Increasing attention is being given to the nature of march fractures since the beginning of the war. Three cases are described here in which the fracture was in the inferior ramus of the pubic bone with no history of trauma, no other break in the pelvic ring and the characteristic roentgen findings of march fracture. The roentgenograms are reproduced. They show rarefaction across the inferior ramus with a zone of periosteal proliferation at the margins, most marked on the upper margin.

Only one such case has been described before and that was in Germany. The roentgen findings were the same as in these cases. These march fractures occur in young men of previous sedentary life who have suddenly been inducted into active military training. They do not occur in older trained and conditioned soldiers.

If a soldier reports gradually developing adductor, hip or pelvic pain a roentgen examination of the pelvis should be made at once.—*Audrey G. Morgan.*

WHISTON, GORDON. Congenital dislocation of the hip with special attention to the aftercare period and late postreductive results. *Surg., Gynec. & Obst.*, Sept., 1943, *77*, 307–314.

Congenital dislocation of the hip, a clinical entity that might better be expressed as congenital misplacement of the hip for its etiology is still largely a matter of conjecture and theory, is not a rare deformity. It is observed more frequently in certain sections of the United States, particularly in the northern states. Outside of the Western Hemisphere, the largest incidence occurs in Italy and France, and at the Rizzoli Institute in Bologna, 3,216 cases have been treated in 33 years.

Methods of Reduction. The closed method of reduction for congenital dislocation of the hip is used for the majority of patients treated in the clinics from which this series was collected and studied. Forty-four of the 48 cases in this group were treated by the closed manipulative method and the technique described by Lorenz was followed in 41 of these 44 cases. Open operation was performed in only 4 patients in the entire series.

Immobilization. The position of immobilization of the hip following reduction by the Lorenz method was that of marked abduction, flexion, and external rotation. This "frog-leg" or first position was maintained for an average period of approximately four months in this series of cases.

The Lorenz second position of less abduction, less flexion, and slight internal rotation was used in almost all the patients treated by the closed method. This position was also maintained approximately four months.

Classification.

1. Class I cures in the Fairbank classification include those cases in which the head of the femur is in the acetabulum and approaches the normal in size and shape as disclosed by roentgen examination. Of the 48 cases reviewed, 18 belonged to this class. The average age was three years at the time of reduction.

2. Class II cures include those cases which show an equally definite anatomical cure but in which the head of the femur is distinctly abnormal either in the direction of being mush-

roomed, varoid, or of being partly or completely worn away by absorptive arthritis. Nineteen cases were in this group.

3. This class includes the considerable number of cases which fail to maintain reduction and in which the femoral head is changed from a posterior dislocation to an anterior position. The anterior repositions are divided into two groups according to the roentgenological findings: (*a*) anterior reposition I means that there is a fairly well formed rounded head opposite the upper lip of the acetabulum with or without the formation of a false acetabulum at this point. Instability is prominent and pain may be noted; (*b*) anterior reposition II includes all the cases with gross changes in the bones. This usually takes the form of flattening and absorption of the head of the femur and a flattening and condensation of the bone at the site of the upper lip of the acetabulum.

Conclusions. From a study of this series of 48 cases which have been under observation from seven to eighteen years after reduction, it is evident that the group in which patients were treated by closed reduction under the age of five years presented late results far superior to those in the older age groups. A period of postreductive immobilization extending over ten months produced more class I cures in this age group than when a shorter period of plaster fixation was used.—*Mary Frances Vastine.*

MacAusland, W. Russell. A study of derangement of semilunar cartilages based on 850 cases. *Surg., Gynec. & Obst.*, Aug., 1943, 77, 141–152.

This is a study of 850 cases of derangement of the meniscus in the knee joint.

Etiology. A derangement of the semilunar cartilage is usually the result of an injury in which the femur is suddenly twisted inward while the weight is being borne on the flexed knee with the lower leg fixed in the position of external rotation. The injury is usually incurred in a young person while engaged in an active sport. Older people, and especially those with an arthritic background, are likely to twist the knee in minor injuries.

Age and Sex. Cartilage derangements are most common among men between the ages of eighteen and forty years. The lesion is seldom seen in old age or in childhood.

Pathology.

1. Lesions of the internal cartilage predominate over those of the external because the former is a less mobile structure than the latter due to its relation to the internal lateral ligament and to its firm adherence to the articular capsule.

2. Types of injured cartilages include: (*a*) fracture of the cartilage; (*b*) the hypermobile cartilage is the result of abnormal laxity of the meniscus at its periphery from damage to the capsular attachments; (*c*) complicating pathology—the cartilage in addition to being fractured or loose is commonly found to be thinned or thickened, calcified, frayed, cystic, or showing degenerative changes; (*d*) the congenital discoid meniscus. This type of cartilage represents a lack of normal development. It appears to be peculiar to the external meniscus. In some cases it persists as a complete disc and in others as a disc with an open center over which is spread a thin curtain of tissue.

Symptoms and Diagnosis.

1. History of injury at which time there was acute pain and a feeling that the knee gave way. Often it was impossible to straighten the knee after the injury or else bending was possible only after someone had pulled on the leg.

2. Recurrent attacks of slipping of the knee associated with a feeling of insecurity at all times.

3. Intermittent effusion.

4. Pain and tenderness in the region of the offending cartilage.

5. The absence of cartilage-thrust. (In the normal knee, when the joint is extended, the cartilage may be felt to bulge or thrust outward between the articular surfaces; this thrust is missing when the cartilage is torn and displaced in the joint space.)

6. Locking of the joint.

Differential Diagnosis.

1. Loose bodies may be palpated or visualized on the roentgenogram. If locking is present, it tends to be momentary.

2. Involvement of the infrapatellar fat pad. In this condition, the pad is palpable and tender on pressure and subpatellar crepitation is usually present.

3. Arthritic joints are differentiated by roentgenograms, which show irregularities in contour of the joint. The history is gradual.

4. Crucial ligament injuries are readily differentiated by the presence of abnormal anteroposterior motion in the knee (a shuck).

5. Injury of the internal lateral ligament gives tenderness and pain localized on the me-

dial side of the knee increased by abduction. The joint is never locked.

6. Bone injuries can be distinguished by roentgenography.

Roentgen Findings. In cases of suspected damage to a cartilage, roentgenograms of both knees should be obtained, not that they are of any diagnostic value (unless the cartilage happens to be calcified) but because they are essential to exclude concomitant lesions. Some observers claim to be able to demonstrate the injured cartilage by injecting various contrast media into the joint and others recommend arthroscopy, but the results of such demonstrations are as yet inconclusive.

Treatment is discussed in detail. The factors that may interfere with obtaining a good outcome by operative intervention are discussed. Among these are the presence of arthritic changes or associated pathology in the joint and the persistent weakness of the quadriceps extensor.—*Mary Frances Vastine.*

Krause, George E., and Thompson, John R., Jr. March fracture of the tibia. *Radiology,* Dec., 1943, *41,* 580–585.

The most common site of fatigue fracture due to marching is in the metatarsals but it may also be seen in the tibia, most frequently at the junction of the upper and middle thirds on the medial surface. Such fractures have been rare in this country because we have not had compulsory military training. They will probably become more frequent now. A number of European articles on the subject are quoted.

Four cases are described and illustrated with roentgenograms. Attention is called to the fact that differentiation between such fatigue fractures and osteogenic sarcoma may present some difficulty.

These fractures are generally incomplete, extending only through the cortex, and the fracture line is narrow and hard to demonstrate. In one of the cases described the fracture was complete. There is abundant callus formation which occurs early.—*Audrey G. Morgan.*

Love, J. Grafton, and Walsh, Maurice N. Protruded intervertebral disks. *Surg., Gynec. & Obst.,* Nov., 1943, *77,* 497–509.

Protruded intervertebral disks as such have been recognized and their clinical importance has been established since the work of Mixter and Barr in 1934. The facts in this study which are of interest to the roentgenologist are outlined.

Anatomy of the Intervertebral Disks. The disk is composed of the central semigelatinous nucleus pulposus and the outer more fibrous annulus fibrosus. It is applied to the surface of the cartilaginous plate which covers the vertebral body and is bounded anteriorly by the anterior longitudinal ligament and posteriorly by the posterior longitudinal ligament.

Pathology and Etiology of Protruded Disks. The protruded portion of an intervertebral disk practically always consists of both nuclear and annular material. The condition is due to trauma, which is most often associated with the lifting of unusually heavy objects.

Incidence of Protruded Intervertebral Disk. The chief of the Section on Orthopedic Diagnosis and his associates at the Mayo Clinic were called on, in 1940, to see approximately 5,500 patients who had backache as a symptom. Approximately 13 per cent of the 5,500 patients were found to have one or more protruded disks as the cause of their complaints.

Diagnosis of Protruded Intervertebral Disk. Some of the findings on examination of the patient include: (1) loss of lumbar lordosis; (2) tenderness over spinous processes of lower lumbar vertebrae; (3) hyperextension of back limited and extremely painful; (4) straight leg raising in the dorsal recumbent position limited and painful; (5) positive Kernig's sign; (6) tenderness on pressure along course of sciatic nerve; (7) Achilles reflex diminished or absent; (8) history of intermittent pain ever since unusual strain on back; (9) pain aggravated by lifting, coughing, sneezing or straining at stool and disturbing patient's sleep.

Contrast Media in the Diagnosis and Localization of Protruded Disks. As the authors' experience has increased they feel that their clinical diagnosis is just as accurate as the roentgenoscopic diagnosis obtained by the aid of radiopaque oil and more accurate than that obtained by the aid of air. Because of the slow absorbability of radiopaque oil and the medicolegal complications which might follow its employment, its use has been practically abandoned. One of the most important uses of the air myelogram in this group of cases is to exclude an unsuspected intraspinal neoplasm and the presence of multiple lesions. Air is practically valueless in thoracic and cervical intraspinal lesions. Its use is restricted almost en-

tirely to those cases in which a lesion in the lumbar portion of the spinal canal is suspected. The interpretation of spinograms (air myelograms) is very difficult and there are many pitfalls.—*Mary Frances Vastine.*

Ehrenhaft, J. L. Development of the vertebral column as related to certain congenital and pathological changes. *Surg., Gynec. & Obst.*, March, 1943, *76*, 282–292.

The development of the vertebrae and the intervertebral discs is described and a correlation is made between developmental peculiarities and certain lesions found in later life. The lesions found in later life which are discussed include:

1. *Congenital synostosis (block vertebrae).* There is complete or partial congenital bony fusion of two or more vertebral bodies without evidence of any or only small amounts of interposed intervertebral disc tissue. This malformation is on the basis of a complete regression of the primitive annulus fibrosus.

2. *Sagittal cleft vertebrae.* Persistence of the ventrodorsal extension of the perichordal sheath with or without the persistence of the chorda or splitting of the notochord in this area may prevent fusion of the laterally situated cartilaginous vertebral halves. Each half may become ossified separately by its anterior and posterior centers with persistence of the sagittal cleft. With weight bearing in later life, such vertebrae may form the "butterfly vertebral bodies."

3. *Lateral half vertebrae or wedge vertebrae.* At first these half vertebrae are cuboidal in shape but they become a wedge as soon as weight bearing occurs. Bilaterally occurring half vertebrae may involve large segments of the spinal column as wedged hemivertebrae at different levels. They are most commonly explained on a faulty shift occurring in the period of development. This unilateral occurring shift will cause an anlage for a half vertebra to remain at the lower and also at the upper end of the unequally shifted vertebral column.

4. *Ventral and dorsal half vertebrae.* These are rare. The explanation for these must be on the basis of faulty vascularization and agenesis of either the anterior or posterior center of ossification. The deformity resulting will be of the gibbous type.

5. *Malformations of the chorda and chordal remnants.* During the state of migration of the notochordal cells during the cartilaginous period of embryonic development, there is definite persistence of the perichordal sheath forming the mucoid streak. Anywhere along the course of this structure which normally regresses completely during the ossification of the vertebral bodies, chordal cell remnants may be found. One of the more frequent abnormalities seen are the outpouchings of the otherwise normal intervertebral discs. Sometimes true extensions of the nuclear material in a wedge-like manner can be seen protruding into the vertebrae. During postmortem examinations notochordal tissue remnants are present in 2 per cent of the cases. Most of these are found in the region of the clivus at the base of the skull.

6. *Congenital weaknesses of the cartilage plates.* In areas where the cartilage plates are penetrated by vessels from the vertebrae, mostly along the peripheral two-thirds and in the center where the axial vessels accompany the notochord, chondrification gaps develop. Multiple spongiosal nuclear prolapses with juvenile kyphosis in the young adolescent group occur mostly in boys subjected to very heavy manual labor. At this age there is still good blood supply to the intervertebral disc tissue. The nucleus pulposus is still rather liquid and easily displaced.—*Mary Frances Vastine.*

Toth, Benedict J., and Wintermantel, Joseph A. An apparently solitary myeloma of bone with subsequent generalization. *Radiology*, Nov., 1943, *41*, 472–477.

Solitary myelomas are rare and apparently less malignant than the more common multiple forms. There are two types. The first is a purely osteolytic lesion with sharp demarcation and little if any expansion, usually located in a single vertebra or the shaft of a long bone. The second is a giant cell type which shows less tendency to generalization and responds better to irradiation.

A case of the latter type is described in a woman aged fifty-three. She had had pain in the right hip for three years before coming for treatment. Roentgen examination on October 20, 1939, showed a solitary tumor of the right pubic bone which later extended to involve the right ischial, innominate and left pubic bones and the soft tissues. At this time chest examination was negative.

On October 31, 1941, roentgen treatment was begun: fifteen treatments were given with a total of 1,700 r through three portals. This was

followed by considerable improvement with increase in red cells and hemoglobin, and in April, 1942, there was considerable recalcification of the area of destruction. A severe reaction with chills and high temperature followed comparatively small doses of roentgen rays. Holzknecht believed such reactions were toxic in character and of good prognosis.

In June, 1942, this patient was readmitted with severe pain in the chest. Roentgenograms of the pelvis at this time showed further improvement but those of the chest showed osteolytic lesions of the ribs with two healing pathological fractures. The patient grew worse rapidly and died on October 28, 1942, three years after the first roentgen study and six years after the beginning of pain in the hip. It is probable that a definite diagnosis of solitary myeloma cannot be made from roentgen examination alone.—*Audrey G. Morgan.*

Echternacht, Arthur P. Pseudotumor of bone in hemophilia. *Radiology*, Dec., 1943, *41*, 565–572.

A case is described in a boy of thirteen who had shown evidence of hemophilia since he was six years of age. This admission to hospital was for a swelling just below the left knee on the anterior surface of the tibia covered with necrotic skin. From roentgen examination a diagnosis of sarcoma of bone was made and roentgen treatment given. The swelling continued to increase in size and extended downward. Disarticulation of the knee joint was decided on. The patient died three days later.

Examination of the specimen showed a large subperiosteal hematoma with massive necrosis of the underlying bone and necrosis and infection of the overlying skin. Evidently the hemophilia had caused subperiosteal hemorrhages which resulted in thickening and proliferation of the periosteum, erosion of the underlying bone and organization and calcification of the hematoma, producing a roentgen image that resembled that of sarcoma.

Three similar cases have been reported in the literature, 2 involving the femur and 1 the bones of the thumb. They are reviewed briefly.—*Audrey G. Morgan.*

BLOOD AND LYMPH SYSTEM

Mahorner, Howard. A method for obtaining venograms of the veins of the extremities. *Surg., Gynec. & Obst.*, Jan., 1943, *76*, 41–42.

Roentgenographic visualization of the veins of the extremities by contrast media is becoming increasingly popular both for the study of relatively recent thrombosis and of long standing occlusion of the deep venous system.

A method is described which obviates the cutting down on the saphenous vein which has heretofore been done in venography of the lower extremities. The method consists of the following steps:

1. The patient sits on the roentgen table and with the legs dependent a 20 gauge needle is inserted into a vein on the dorsum of the foot or on the ankle. The course of the internal saphenous is anterior to the internal malleolus and it is relatively superficial, usually permitting the insertion of a needle without an incision.

2. The tubing of an infusion set containing normal salt solution is connected with the needle. The infusion is permitted to drip relatively rapidly.

3. The patient lies down on the table and a gum rubber tourniquet is applied around the leg, usually at the junction of the middle and lower thirds, sufficiently tight to impede circulation in the superficial veins. This serves to shunt the infusion from the superficial into the deep system.

4. Twenty cubic centimeters of diodrast (35 per cent) is slowly injected into the tubing of the infusion just above the needle.

5. Five seconds after the diodrast is completely delivered, the roentgen exposure is made.

6. After the exposure the infusion continues to run for 200 cc. in order to wash the diodrast from the veins.—*Mary Frances Vastine.*

Baker, E. C., and Sedwitz, S. H. Observations on venography of the lower extremities. *Radiology*, Nov., 1943, *41*, 451–458.

An excellent method of studying the veins of the lower extremities is by a series of multiple roentgenograms made over varying periods of time. The authors used diodrast injected slowly over a period of two minutes. They place two lead screens, one on either side of the top of the Bucky table, wide enough so that the space between them allows a coverage of half of a 14 by 17 inch film. The screens are long enough to reach from the lower abdomen to the [illegible]. Three pairs of exposures are made, the first covering the ankle and lower leg, the second the upper leg and knee and lower thigh, and the third the upper thigh and lower pelvis.

The anatomy of the veins of the lower [illegible]

is reviewed. Physiological observations can be made from these serial roentgenograms and valuable pathological conclusions drawn. The passage of the dye upward is retarded in severe varicosities and in veins that are dilated and tortuous. There are free anastomoses between the deep and superficial veins of the leg and dye may pass from the one to the other rapidly. Retrograde flow of the dye has been seen in both deep and superficial block. This method should be used before injecting any sclerosing solution or performing any surgical operation. Up until a year ago when the authors first started venography they had 10 per cent post-operative complications following massive injection and ligation and section of the long saphenous vein. Since beginning venography before operating there have been no such complications in 120 cases. The method is also valuable in traumatic phlebothrombosis. There is no danger of diodrast causing loosening of an embolus. The method should be better known to surgeons.—*Audrey G. Morgan.*

Figi, Frederick A., and Watkins, Charles H. Hereditary hemorrhagic telangiectasia. *Ann. Otol., Rhin. & Laryng.*, June, 1943, *52*, 330–341.

Hereditary hemorrhagic telangiectasia is an inherited abnormality characterized by the presence of localized angiomas or telangiectases which have a tendency to bleed. These vascular lesions occur most frequently in the nasal and oral mucous membranes where they often give rise to severe and at times fatal hemorrhage. The entity was first recognized by Rendu in 1896 and was elaborated upon five years later by Osler. In 1934, Houser directed attention to this disease and reported the case of 4 patients all of whom were blood relatives.

During the past twenty years, 20 cases have been recognized at the Mayo Clinic. None of these patients were blood relatives. No demonstrable changes in the coagulation factors of the blood nor undue bleeding after surgical procedures was encountered. In all of the cases seen at the Mayo Clinic, epistaxis was the presenting complaint.

Differential diagnosis must be made from hemophilia, purpura hemorrhagica, aplastic anemia and acute leukemia.

The disease is due primarily to a defect of the walls of the capillaries and venules and therapy is not likely to benefit this. Electrocoagulation has given the best results with the authors. Radium is contraindicated as it is felt that the atrophy and dryness of the nasal mucosa which results greatly increases the tendency to later bleeding.—*Mary Frances Vastine.*

ROENTGEN AND RADIUM THERAPY

Barner, John L. X-ray therapy in the Army. *Radiology*, Nov., 1943, *41*, 483–485.

The author who is a Major in the Army Medical Corps discusses the changes that have taken place in roentgen-ray service since the beginning of the war. Roentgen therapy is now used to some extent throughout the whole Army Medical Department. The roentgen machine used in the combat zone is a portable roentgenographic unit which may be used also for superficial therapy, as for infections and dermatoses. The great majority of cases that require roentgen treatment reach the General Hospitals where there is every facility for proper treatment, as in civilian hospitals. There are now 7 General Army Hospitals in the United States and two outside the country in which both deep and superficial roentgen treatments are given. The names and locations of these hospitals are given and the equipment and treatment discussed.

Calculated on Army statistics for the past in an army of five million men there will be about 2,000 to 3,000 cases of cancer per year and 10,000 cases of non-malignant tumors. There is also now a much larger number of women in the Army than ever before and this will increase the number of cancer cases. Because of the close observation of men in the Army, which is not possible in civilian practice, many cases will be seen earlier in the curable stage, so that the men may be returned to duty. Here in this army of millions the principle of early recognition and early treatment of cancer can be practiced as never before.—*Audrey G. Morgan.*

Pfahler, George E. A review of the Scott wide field x-ray treatment. *Radiology*, Nov., 1943, *41*, 468–471.

Scott's method consists of treatment with small doses of low voltage roentgen radiation applied from the head to the upper part of the lower extremities, both in front and behind. It is given for its tonic and stimulating effect on the body as a whole and not for the destruction of pathological tissue. The dosage and interval between treatments must be determined by this tonic effect.

Scott began this work in 1920–1921 at the London Hospital. The first 50 cases were kept under observation for a year to see that no harm was done. Not only were there no bad effects but there was distinct improvement in all cases. There was nothing to suggest anemia or leukopenia in any case.

The differential sedimentation test has been found of value in testing results and determining the saturation point. The author has been using this method for more than six months and has seen no harm and some benefit from it.

In the discussion Dr. Helen B. Flynn of Chicago said that in this treatment the patient must be watched carefully for signs of toxemia. Each patient will respond differently. Dr. Gendreau of Montreal said they had been using the method in the Montreal Hospital but that it is dangerous and must be carefully studied. Dr. Godfrey of Glendale, California, said he had seen no bad effects from the treatment. He believed that in the cases in which bad effects had been reported curious metabolic changes had occurred which released toxic substances that acted as a systemic poison. Dr. Pfahler, in closing, emphasized the fact that this was a stimulating treatment for normal tissue and not a destructive one for pathological tissue. It has no relation to the high voltage body treatment given for leukemia. The effect of any dose of roentgen rays depends to a great extent on the volume irradiated. Naturally when the whole body is irradiated the constitutional effect is very great and this must be taken into consideration. Low voltage irradiation does not injure the blood-forming organs.—*Audrey G. Morgan.*

Rosh, Rieva, and Quinn, William P. Roentgen rays in the treatment of cervical lymphadenitis. *Radiology*, Nov., 1943, *41*, 464–467.

The follow-up of 419 patients with cervical lymphadenitis treated at Bellevue Hospital has shown the good effects of irradiation in this condition. Small doses of roentgen rays are known to have a good effect on inflammatory conditions. A standard method of treatment for all cases is not possible. In children and younger patients with superficial lesions, low or medium voltage treatment was given. In patients with deep large nodes, particularly if several nodes had become confluent, high voltage deep treatment was used. The total dose given was 700 to 900 r, in air, repeated if necessary after six to eight weeks.

Regression and healing of the nodes and sinuses was usually complete. All types and stages of cervical adenitis were treated.

Roentgen examinations of the chest were made in all cases. It was found that there was no active pulmonary tuberculosis unless the supraclavicular, axillary or mediastinal nodes were involved.

The results are of course influenced by the economic condition of the patients. Run-down, overworked and poorly nourished patients do not respond as well as those in better condition. —*Audrey G. Morgan.*

McFarland, Joseph. The mysterious mixed tumors of the salivary glands. *Surg., Gynec. & Obst.*, Jan., 1943, *76*, 23–34.

The mixed tumor was first described by Virchow in 1863. It is not a common finding since the author has been able to find only 400 cases in a twenty-five year search.

These tumors have the following characteristics:

1. They are definitely encapsulated and do not infiltrate unless their capsule is opened.
2. The tumor usually projects externally but the skin stretches over it and rarely ulcerates.
3. One hundred of the writer's 400 cases have recurred.
4. Every mixed tumor consists of interstitial and parenchymatous tissues, the proportions and conditions of which vary.
5. Metastasis is extremely rare. Perhaps it never occurs.
6. Local interference with function is rare.
7. Treatment with roentgen rays and radium has not proved of benefit.

Excision of the tumor is indicated only if:

1. The patient insists on the operation because of the disfigurement. (He should be advised of the possible sequelae, viz., salivary fistula, facial palsy, or recurrence.)
2. Limitation of mandibular movement which makes opening of the mouth difficult.
3. Pain from pressure upon the sensory nerves.
4. Sudden rapid increase in the size of the tumor.—*Mary Frances Vastine.*

Buckman, Lewis T. Carcinoma of the middle ear and mastoid. *Ann. Otol., Rhin. & Laryng.*, March, 1943, *52*, 194–201.

A case of carcinoma of the middle ear and mastoid is reported and a discussion of this entity is presented. Statistics vary from an incidence of 1/4000 to none in 20,000 cases. The following conclusions are reached:

1. Carcinoma in this location is usually preceded by a long period of otorrhea.

2. Homolateral seventh nerve paralysis is usually an accompaniment sooner or later.

3. There may be polypoid tissue in the middle ear which is friable and perhaps, grayish.

4. Pain is late.

5. Roentgen examination may not be helpful. It usually is not.

6. Treatment is unsatisfactory. In 1930, Fraser described his sleeve operation on the canal and the postoperative use of radium. He felt that if the mastoid was involved in the carcinomatous process there was little hope. In 1935 Schall described a technique of wide removal of the cutaneous nerves and the canal together with radical mastoidectomy followed by irradiation. His results were favorable.—*Mary Frances Vastine.*

Fisher, Gilbert E. The use of radium in conduction deafness. *Ann. Otol., Rhin., & Laryng.*, June, 1943, *52*, 473–476.

Akaiwa and Takeshima in 1930 carried out experiments on the effects of irradiation of the lymph nodes found in the popliteal spaces of rabbits. Thirty minutes after irradiation, the lymph follicles of these nodes were enlarged. After one hour, the nuclei of many of the cells began to disintegrate. This disintegration reached its height in two to six hours. From this time on, marked phagocytosis was noted. Because of this disintegration of lymphocytes there was a considerable decrease in the number of these cells in the lymph follicles after forty-eight hours. Then followed regeneration so that after the seventh day the lymph node resumed its normal appearance except for an increase in connective tissue. Microscopically there was an increase in the size of the node for the first two hours following irradiation. Then there was a gradual decrease in the size of the node, and in two weeks, the node was smaller than normal.

The author has used a radium applicator in the treatment of 45 cases of conduction deafness in which lymph tissue was noted to be obstructing the eustachian tube. The capsule is made of platinum 0.5 mm. in thickness and this is loaded with 50 mg. of radium. The capsule has a coating of rubber 0.7 mm. in thickness. A 1 per cent solution of cocaine is sprayed into each inferior meatus. A cotton-tipped applicator moistened with 3 drops of 10 per cent cocaine is then passed along the floor of each inferior meatus. After five minutes, the radium applicator is inserted into the nasopharynx. A 2-gram minute treatment is given on each side.

Following the treatment there may be some stuffiness for one week with some increase of post-nasal discharge. This is followed by a decrease in the amount of the post-nasal discharge.

Conclusions.

1. Nasopharyngeal lymph tissue will undergo compensatory hypertrophy producing a large recurrent mass of adenoids and a "granular" pharyngitis in almost every child whose adenoids have been removed prior to puberty.

2. Large masses of nasopharyngeal tissue which obstruct the eustachian tubes are definite etiologic factors in conductive deafness.

3. Atrophic changes can be readily produced in this tissue by exposing it to the gamma rays of radium.—*Mary Frances Vastine.*

Jackson, Chevalier L., and Blady, John V. Criteria for the selection of treatment of cancer of the larynx. *Arch. Otolaryng.*, May, 1943, *37*, 672–679.

Much has been written about the relative advantages of irradiation and surgery in the treatment of cancer of the larynx, and too often these two methods have been considered from a competitive standpoint.

The authors' criteria for the selection of a method of treatment of cancer of the larynx are:

1. The presence or absence of cervical metastases.

2. The location and extent of the lesion, as evidenced by its appearance on direct and indirect laryngoscopy and by lateral and planigraphic roentgenographic study.

3. The motility and mobility of the laryngeal structures.

4. The histologic character of the lesion.

5. The general physical condition and temperament of the patient.

The indications for laryngofissure and laryngectomy include:

1. Lesions occupying the middle third of one vocal cord are suitable for laryngofissure by the "clipping" technique.

2. Lesions reaching the anterior commissure and even involving the opposite cord are amenable to extirpation by the laryngofissure route.

In such cases the "anterior commissure" technique should be used.

3. Lesions in which the growth is cordal but has reached the posterior end of the cord and produced impairment of motility, or has extended subglotically, ordinarily call for total laryngectomy.

4. Lesions in which the tumor has invaded cartilage (but not muscles) also call for laryngectomy, provided there are no metastases.

The indications for irradiation include:

1. Lesions unsuitable for laryngofissure and for which laryngectomy is contraindicated by the age, physical condition or temperament of the patient.

2. "Inoperable" growths which are extrinsic by origin or extension or which have cervical metastases.

3. Lesions which have reached the posterior extremity of the cord but have not produced impairment of motility of the cord.

There are those who minimize the importance of the histopathologic picture, but the authors believe that the ultimate prognosis will be most favorable in cases of the better differentiated, slower growing, lower grade tumors, regardless of the method of treatment. In a recent review of cases of patients treated by irradiation alone, 95 per cent of patients with Grade 1 tumors, 70 per cent with Grade 2 tumors and only 40 per cent with Grade 3 tumors survived five years or more.—*Mary Frances Vastine.*

New, Gordon B., and Stevenson, Walter. End results of treatment of malignant lesions of the nasopharynx. *Arch. Otolaryng.*, Sept., 1943, *38*, 205–209.

Two hundred and seventy-one patients suffering from malignant lesions of the nasopharynx received treatment. Biopsy was made in all cases and all revealed evidence of malignancy except 37. In these 37 cases there was a definite clinical picture of malignant disease but one biopsy did not reveal the malignant cells. However, the subsequent course of the disease confirmed the clinical diagnosis. Most of the malignant tumors of the nasopharynx are epitheliomas, usually high grade squamous cell epitheliomas Grade 4 (Broders' method), which, fortunately, are radiosensitive. The epitheliomas usually appear as ulcerative lesions in Rosenmüller's fossa while the lymphosarcomas are large bulky tumors. The youngest patient was four years of age and the oldest eighty with an average of 43.3 years.

The 234 patients with malignancy proved by biopsy were treated by irradiation. Symptomatic relief following treatment by irradiation was sometimes striking. The pain and headache were much better or sometimes entirely cleared up. Double vision, due to palsy of the sixth nerve, was eliminated by the treatment in some cases. Deafness from obstruction of the eustachian tube by pressure of the tumor was improved. Lymph nodes of the neck were often reduced in size so that the patient was much better and more comfortable at least for a time. In several cases roentgenograms of the sella showed destruction of the posterior clinoid processes from extension of the tumor. After treatment, regeneration of the bone occurred in a remarkable fashion.

Of the patients who had sarcoma, 26.8 per cent were alive five years after treatment and of the patients who had squamous cell epithelioma 8.9 per cent were alive. Of the total number of patients who had malignant lesions, 13 per cent were living after five years. About twice as many patients with squamous cell carcinoma were alive in the group without involvement of the lymph nodes at the time of the treatment as in the group with such involvement. In other words, 15.6 per cent of the patients with squamous cell carcinoma who did not have palpable lymph nodes and 7.4 per cent of the patients who had palpable lymph nodes were alive five years after treatment.—*Mary Frances Vastine.*

Engler, Clarence W. Roentgen therapy of laryngeal tuberculosis. *Ann. Otol., Rhin. & Laryng.*, Sept., 1943, *52*, 655–665.

The most popular local measure in use today for the treatment of laryngeal tuberculosis is electrocauterization (voice rest excepted). It is universally agreed that laryngeal tuberculosis is practically always secondary to pulmonary tuberculosis.

Rickmann has classified laryngeal tuberculosis as follows:

1. Productive or proliferative type in which the lesion is fairly well defined and localized. A tendency toward healing is present.

2. Exudative type. The lesions are diffuse so that several structures in the larynx may be the seat of disease at the same time.

3. The mixed type in which both productive and exudative lesions exist in the same larynx. In all three types, infiltration and ulceration may be present.

Thirty-eight patients were given roentgen therapy. The rationale of the treatment adopted in this series took into account the fact that the inflammatory component could be managed by relatively small doses of roentgen rays and that the chronicity factor could be controlled by multiple doses at relatively long intervals and continued over a period of several months.

Summary and Conclusions.

1. Laryngeal tuberculosis is practically never primary but always a part of the general or pulmonary tuberculosis and must be considered and treated as such.

2. Good general resistance and a successful collapse therapy are more important in healing of the larynx than are any local therapeutic measures.

3. The laryngeal lesion may heal while the pulmonary disease progresses.

4. In a few cases the lung condition improved while the laryngeal lesion remained unimproved or progressed unfavorably.

5. Laryngeal tuberculosis may be divided into the productive, exudative, and mixed types.

6. Opinion regarding the type of laryngeal tuberculosis that will be improved by roentgen treatment varies with the enthusiasm and experience of different authors.

7. The cases reported in this series were not selected. Thirty-eight patients were given roentgen therapy. Of these, there was healing of the larynx in 21 per cent; 16 per cent showed some improvement. Twenty-one per cent remained unchanged and 42 per cent became worse.

8. All 16 cases (42 per cent) in which the larynx became worse were of the exudative type.

9. It is advised that a large series of selected patients be given roentgen therapy in order to determine what relative value it has as compared with other local measures and also what type of lesion is benefited by it.—*Mary Frances Vastine.*

Martin, Charles L. Cancer of the nasopharynx. *Ann. Otol., Rhin., & Laryng.*, March, 1943, *52*, 146–160.

Cancer of the nasopharynx originates most frequently in the pharyngeal tonsil and the fossae of Rosenmüller and much less often in the periphery of the choanae and the posterior nasopharyngeal wall. Many of these are incorrectly diagnosed even after secondary invasion. Woltman stated that only 1 out of 20 cases examined at the Mayo Clinic prior to 1922 had been correctly diagnosed.

Undifferentiated epitheliomas, lymphoepitheliomas, lymphosarcomas and plasmocytomas respond satisfactorily to irradiation whereas adenocarcinomas, well differentiated epitheliomas and the spindle cell carcinomas respond poorly.

The subject is discussed under the following headings:

1. Local growth. Only half of New's 194 cases complained of symptoms produced by the primary growth. Thus, it is usually the manifestations due to the secondary extension which first bring the patient to the physician.

2. Intracranial extension. This occurs in about one-third of the cases. The exact mode of the extension is not known. The neoplasm enters the cranial vault just lateral to the sella in the region of the foramen lacerum and may extend either anteriorly or posteriorly. The dura is pushed upwards but practically never invaded. No dysfunction of the pituitary gland has been seen from this extension. Vertical sections of the middle fossa show the nerves to be placed in the following order if one reads from below upwards: the sixth branches of the fifth nerve, the third nerve, the fourth, the first. Extension of the nerve symptoms due to extension of the tumor into the middle fossa follows the same order. (The posterior cranial nerves are likely to be compressed by extracranial rather than by intracranial metastases.) Auditory nerve symptoms practically never occur. The patient with early intracranial extension usually complains of double vision from internal strabismus, pain or anesthesia in the face, nose or teeth.

3. Lymph node involvement. Those which lie in the deep cervical region below the tip of the mastoid are the first to be involved. There is later dissemination to the posterior cervical chain, and occasionally the submaxillary and submental glands are involved.

4. Generalized metastases. Extension below the clavicles with mediastinal lymph node or pulmonary involvement is not infrequent. Metastases to bones, liver, kidneys, spleen or retroperitoneal lymph nodes are usually present at this stage.

5. Treatment. Surgery has accomplished relatively little in the treatment of these tumors. Approximately 85 per cent of the primary le-

sions are so radiosensitive that they can be completely eradicated by irradiation. The exact technique and dosage used by the author in treatment is outlined. He administers irradiation to the base of the skull and the thorax as well as the lesion itself in the early cases.—*Mary Frances Vastine.*

LENZ, MAURICE. X-ray treatment of diseases of the larynx. *Ann. Otol., Rhin. & Laryng.*, March, 1943, *52*, 85–108.

Roentgen treatment is employed chiefly in three groups of diseases of the larynx, viz., chronic inflammation, benign tumors and cancer.

1. Inflammation of the larynx. The inflammatory diseases in which roentgen treatment has been carried out most often are tuberculosis, blastomycosis and scleroma. (Though roentgen treatment of laryngeal tuberculosis has been popular in central Europe for fifteen years it has not been generally accepted in the United States.)

2. Benign tumors of the larynx. Roentgen treatment of benign tumors of the larynx has been successful chiefly in a few hemangiomas and various types of papilloma. Single papillomas which are uncommon and usually occur in adults should not be treated by roentgen irradiation. The need for roentgen treatment of multiple papillomas in children has been reduced to a minimum as they are now effectively treated by estrogen therapy.

3. Cancer of the larynx. Details of the present technique employed by the author at the Presbyterian Hospital, New York, are given. Eighty-nine cases of carcinoma of the larynx were treated between 1932 and 1936. Of this number, 14 had treatment following total laryngectomy. Four of these (28.6 per cent) were clinically free from cancer in January, 1942. Five received roentgen treatment after partial laryngectomy. Three of these (60 per cent) were clinically free of disease in 1942. Seventy cases received roentgen treatment only and 13 (18.6 per cent) were clinically free in January, 1942.

It is often difficult to decide whether in a particular case of carcinoma of the larynx it is better to perform a laryngofissure and cordectomy, a total laryngectomy or to rely upon roentgen treatment. Roentgen treatment of cancer of the larynx is a serious undertaking. The reaction to it is severe and it is not tolerated by all patients.

Microscopic classification of cancer of the larynx by itself is no longer regarded as a reliable guide either to radiosensitivity or to radiocurability of the process. Prognosis seems rather to be influenced by:

1. The location of the primary tumor. Those which are located primarily in the region of the arytenoid cartilages seem to have the poorest prognosis.

2. Local extent of carcinoma of the cords. There is no doubt that the extent of the cancer on admission definitely influenced the results of roentgen treatment in the series treated.

3. Cancer of the arytenoids. Invasion of the arytenoids by carcinoma whether this is an extension from a primary site on the mucosa covering the arytenoids or is a spread from a cancer of the cord, often signifies that the cancer is incurable by roentgen treatment. Three factors contribute to the gravity of invasion of the arytenoids by cancer: (*a*) cancer of the arytenoids is usually silent early whereas cancer on the free edge of the cords produces hoarseness and therefore an early diagnosis; (*b*) a rich lymphatic network covers the arytenoids so metastasis is early; (*c*) the arytenoids are located in a sort of pouch and drainage is uphill and inadequate. Infection therefore persists here so that necrosis, especially of the cartilages, arises and is made worse by roentgen irradiation.

4. Cancer of the epiglottis. Cure may result from roentgen therapy, even if most of the epiglottis has been invaded by the cancer and has undergone necrosis after roentgen treatment. This is probably because in necrosis of the epiglottis, drainage is downwards towards the ventricle, and the necrotic material is emptied into this cavity whence it is coughed up and expectorated.

5. Metastases to cervical lymph nodes. Naturally those patients whose cancer on admission has already extended beyond the cord tend to present metastatic lymph nodes more often than those in whom it is still limited to the cord.—*Mary Frances Vastine.*

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THE PRODUCTION OF GROWTH BY THE ACTION OF THE PITUITARY GLAND ON THE VASCULAR AND HEMOPOIETIC SYSTEMS

INTERRELATIONSHIP BETWEEN THE LUNGS AND THE PITUITARY GLAND*

By ROBERT C. MOEHLIG, M.D.
DETROIT, MICHIGAN

IT IS the purpose of this paper to present evidence supporting the view that the pituitary gland produces growth by the formation of blood vessels and by supplying blood to the tissues. Furthermore, it will be shown that there is a reciprocal relationship between the lungs with their vital functions of oxygenation, and respiratory water metabolism and the pituitary gland. The influence of this gland on the mesodermal vascular and hemopoietic systems is of particular interest in this paper.

That growth may and does take place by virtue of an increase in the number of blood vessels and blood supply to a part is shown in the condition, arteriovenous fistula. In this departure from the normal blood supply, growth proceeds without the presence of a pituitary eosinophil adenoma or hyperplasia and most certainly without a generalized increase of the anterior pituitary hormone. There is present, as a rule, an enlargement of the soft tissues as well as of the bones in the affected part. This represents a localized gigantism or acromegaly.

Horton[20] reported 23 cases of hemihypertrophy of the extremities associated with arteriovenous fistula. The report covered a period of two years at the Mayo Clinic. That the increase in blood flow to an extremity may alter the normal growth of bones is shown in these cases of arteriovenous fistula. Horton said that the fact that the age of the patient can be estimated fairly accurately by the degree of ossification of various bones is well known. If the ossification of the wrist and hand in one of his cases were offered in evidence of age it would be valid only as applied to the right (normal) member. Three carpal bones were ossified in the normal member with the arteriovenous fistula. The anatomic age of the right hand was approximately five years but the subject's age was only three years. It is of interest that in 5 of Horton's 23 cases, hypertrophic arthritis was present in the terminal joints of the involved extremity and bone atrophy was present in 2 cases.

In Figure 1 is shown an amputated hand with an acquired arteriovenous fistula injected with red lead. Despite the suturing of the radial and ulnar arteries with result-

* From the Department of Medicine, Harper Hospital, Detroit, Michigan.

Fig. 1. Hand with arteriovenous fistula showing decreased blood supply due to ligation of radial and ulnar arteries. Cirsoid conditions of vessels is well shown.

ing retardation and diminution of the blood supply, the tortuosity of the blood vessels and great vascularity of the hand are apparent.

In 18 of Horton's cases there was an increase of 0.5 to 7 cm. in the length of the bones in the abnormal extremity. The temperature was from 1 to 6.5° higher than in the corresponding extremity. The oxygen saturation of the blood from the veins of the affected extremities was invariably higher than the normal extremities. This same difference was noted in intracranial arteriovenous fistulas by studying the oxygen content of the internal jugular vein.

If an arteriovenous fistula can produce an overgrowth of an extremity by increasing the blood supply, is it possible that the pituitary produces body growth by developing the circulatory system of the body and by the production of blood? If so, then there is no need to assume the presence of the so-called specific hormones or polyhormones since all endocrine glands would be affected by this mechanism. Not alone would the endocrine glands be affected but the body as a whole.

Certain states of congenital hypopituitarism are associated with defective growth development resulting in dwarfism. In the congenital condition cretinism, dwarfism is also present and as pertinent to the present discussion, the state of the pituitary in this disease is of paramount importance. In a review of the pituitary findings in cretinism and congenital hypothyroidism, it was found that this gland "undergoes structural changes. The majority believe that hyperplasia is present, confined almost entirely to the chromophobe or chief cells. Some believe that the gland atrophies. From a clinical standpoint everything points to a hypofunction of the pituitary in the hypothyroid state. Enlargement of the gland does not necessarily mean, as some believe, an increased function. Cretinism with goiter certainly does not indicate that the goiter is an actively secreting gland but, on the contrary, is a degenerative type of gland enlargement."[46]

Since the pituitary function is reduced in cretinism, then the capillary and vascular system development should in this congenital and developmental state be aplastic or show evidence of maldevelopment. This is based on the assumption that a normally functioning pituitary is necessary for a normally developed vascular system. Since the evidence favors the view that the pituitary is a congenitally underfunctioning gland in cretinism, then the state of the

vascular system in this disease should be an undeveloped one and so it is found. Some of the evidence is as follows: Starlinger,[59] withdrawing blood from the veins of cretins noted that this could be performed much easier in those with a goiter than in those without. He therefore concluded that the vascular system in hypothyroidism remains in a hypoplastic condition if the disease is present during the first years of life. If, however, hypothyroidism is present later in the developmental period of life, this hypoplastic state of the vascular system does not take place and normal conditions prevail.

DeQuervain and Wegelin[55] said that four-fifths of all cretins show moderate to severe changes in the capillaries. Gehri,[13] of Wegelin's Clinic, studied the capillary system of 155 cretins. She found that the more severe the grade of cretinism, the more severe the grade of capillary system disturbance. Ninety-three of the 155 belonged to the severe type of cretinism. And in this group 3.2 per cent showed normal capillary development, 9.6 per cent showed mild involvement, 39.7 per cent were moderately affected and 47.5 were severely affected.

The condition of the capillaries as found in cretins by Gehri has been substantiated according to Wegelin by Jaensch, Gunderman, Wittneben, Müller and Bock. Wegelin stated that no athyreotic individual or cretin ever shows a fully normal capillary picture. It is the pituitary gland, being in a hypofunctional state in cretinism, which accounts for the pathological capillary findings and not the thyroid gland.

An example of the influence of the pituitary gland on the capillary system is seen in the congenital defective condition, anencephalus. It has been found that the pituitary gland is defectively developed in that group of cases in which the anterior portion of the cerebrum is involved. This leads to the condition, apituitarism, and is a true congenital apituitarism. Many writers have shown the defective development of the pituitary in anencephalus.[4,6,8,10,31,32,33,42,50] It has been shown that the adrenal cortex is defectively developed in this condition and is secondary to the pituitary defect.[44] Cushing[9] agreed with this view. He stated that nature performed for us a hypophysectomy in the anencephalic fetus with resulting hypopituitarism associated with aplasia of the adrenal cortex.

The whole vascular system as well as the heart is poorly developed in anencephalus and it is reasonable to assume that since the syndrome has the features of apituitarism the pituitary is also responsible for the vascular-cardiac underdevelopment and the latter is the prime cause of the hypoplastic state of the viscera and stunted body growth.

As is known, the pituitary influences the phenomenon of menstruation and it exercises control over blood vessel development of the myometrial endometrium mediated probably by the estrogenic and progestational hormones. We know that the anterior lobe initiates and maintains gonadal function and is a factor in inducing menstrual bleeding. The development of the capillaries in the endometrium is of great importance and it seems safe to say that the pituitary is necessary for the development of the endometrial capillary system. This would also hold true for the vascular system of the placenta of pregnancy.

The assumption that the chromophil cells of the pituitary control the development of the capillaries and hemopoiesis plus the well known pharmocologic effect of the posterior lobe on the capillaries would furnish a logical explanation for the phenomenon of menstruation. While it is not the purpose of this paper to enter into a lengthy discussion of menstruation, nevertheless if the principles as outlined in the paper are presumptively correct then there is a logical explanation for this function.

Hartman,[17] in a recent review, "presented informally what appear to be the more basic facts which must be considered in formulating a working theory on the cause of menstruation." The observations of Markee[41] on the vascular phenomena seen in intraocular endometrial transplants are stressed.

Hartman, basing his observations on the work of Markee, said: "The vascular changes preceding menstruation, whether in a normal ovulatory or an anovulatory cycle, or after cessation of estrogen, progesterone or any other steroid, are practically the same."

He then goes on to describe four stages of the vascular changes: 1. Stasis, with or without general vascular dilatation in the transplant, occurs one to five days before the flow. This is the stage of congestion. 2. A constriction of the spiral arteries occurs four to twenty-four hours before the hemorrhage. The blood is thus shut off from the area supplied by the artery and a marked blanching of the field results. Necrosis of the tissues which ends in sloughing is most probably due to the anoxia begun during the stage of stasis and completed with the anemia just described. This stage is always present. 3. Hemorrhage from capillary, arterioles and venules. 4. "A cessation of bleeding takes place through the final constriction of the arteriole. According to Daron, this constriction may occur as far back as the myometrium but in Markee's experiments endometrium only was transplanted. Markee's chief contribution centers about the phenomenon of regression. It is the common denominator of menstrual bleeding from every type of endometrium. Observing it in the ocular transplant it is possible to predict the approximate hour of uterine bleeding."[17]

He is of the opinion that an extragonadal influence on rhythms in the female genital tract seems certain. "To discover what this influence is (adrenal? posterior pituitary?) may eventually be of real significance for the explanation and control of uterine pathology."

One could readily postulate that the anterior lobe of the pituitary with its eosinophil and basophil cells produced the development of the endometrial capillaries and the blood, mediated by the estrogenic ovarian hormone of the ovary and the chromophil cells of the pituitary. Then around the fourteenth day of the menstrual cycle the antagonistic progestational hormone of the corpus luteum inactivates the posterior lobe hormone of the pituitary permitting the secretory phase of the endometrium to develop with its vascular Swiss cheese pattern of spiral capillaries. However, if gestation does not take place then the posterior lobe secretion, near the end of the menstrual cycle, probably a few hours before the flow, overcomes the decreased corpus luteum secretion, and constriction of the arteries occurs. It is of course well known that the corpus luteum degenerates towards the end of the menstrual cycle and, furthermore, the antagonistic action of the progesterone and posterior pituitary secretions is well known.

Thus both the anterior and the posterior lobes of the pituitary with their respective actions play a major rôle in the phenomenon of menstruation.

Certain facts indicate that the eosinophil cell of the pituitary is responsible for the vascular system development whereas the basophil cell produces hemopoiesis through stimulation of the reticulo-endothelial system. There is a close relationship between the chromophil cells as well as the adenomas formed from these elements. Their juxtaposition anatomically is also shown in their physiological relationships. The eosinophil adenoma produces gigantism or acromegaly and the basophil adenoma, basophilism or Cushing's syndrome. In both conditions there are found, as a rule, the following:

1. Osteoporosis.
2. Hypertension.
3. Hyperglycemia, glycosuria, or a lessened glucose tolerance.
4. Erythremia or a tendency to polycythemia.
5. Amenorrhea in the female and impotency in the male.
6. Weakness and ease of fatigue.
7. Hirsutism.

The eosinophil cell produces growth of the body by its ability to develop the vascular system. If this is true then it becomes a corollary that a normal or near normal de

velopment of this system is essential for growth, otherwise the nutritive elements of the blood would not be delivered to the protoplasm of the cell. The very size of the tissues indicates that there is an increased development of the vascular system in acromegaly and gigantism and this has been demonstrated in these conditions. At least two essential factors for growth are produced by the pituitary, the vascular system and the blood. Growth is accomplished by the hormones of the pituitary which bring about the formation of the vascular system and the blood forming elements. Thus one could understand the far reaching effects of the pituitary gland so that by the formation of these basic elements its effects are felt in all parts of the body. Its euphonious title, "leader of the endocrine orchestra," is well chosen.

As justification for the view that the pituitary is a major factor in the development of the vascular and hemopoietic systems, further data are herewith submitted:

In renal rickets or renal dwarfism, pituitary defects with diabetes insipidus are one of the most frequent findings. Bader[3] showed that there is *defective development of the systemic blood vessels as well as of the renal glomeruli*. Congenital lesions of the heart are common as is cardiac hypertrophy associated with degenerative myocardial muscular changes. Mitchell[43] found cardiac enlargement in 46 out of 78 cases of renal dwarfism. Amenorrhea, imperfect development of genitalia and breasts is a frequent finding. Of 78 cases reviewed by Mitchell, 64 had polyuria. Secondary anemia was present in all cases. The latter finding and the defective development of the systemic blood vessels help in a large measure to explain the dwarfism. In view of the pituitary defect, it is a natural assumption that this gland is responsible, among other things, for the defective vascular system development as well as for the anemia.

Moehlig and Bates[47] reviewed the literature on the influence of the pituitary on erythrocyte formation. It was concluded that "the pituitary has a very important influence on erythrocyte formation. Primary disease of the suprarenal cortex results in secondary pituitary changes thus accounting for many signs and symptoms erroneously ascribed to the suprarenal cortex. The specific and selective embryohormonic relations of the pituitary gland to mesodermal tissues is a reasonable explanation for the polymorphic signs and symptoms of pituitary disturbances."

We showed by experimental work on dogs that bilateral adrenalectomy produces soon after this operation a pronounced increase of the pituitary basophil cells associated with polycythemia. Our findings are similar to those of others while another group reported hypoplasia of the pituitary after this operation (literature by Herrick and Finerty,[18] Moehlig and Bates[47]). Recently White and Dougherty[65] found that continued daily injections of adrenotrophic hormone into mice resulted in an increase in hemoglobin and red cells, an absolute lymphopenia and an increase in polymorphonuclear leukocytes. By means of its trophic influence on the adrenal cortex, pituitary adrenotrophic hormone maintains a physiological control over the numbers of circulating erythrocytes and lymphocytes. One may also assume that the hormone stimulates the whole reticulo-endothelial system, including the bone marrow, such as is seen in the case reported with adrenal cortex tumor and pituitary basophilism. These authors cite the work of others showing the influence of the pituitary on erythrocyte formation.

In Addison's disease, in which there is a more or less gradual loss of adrenal tissue and function, the pituitary is found to be in a degenerative state.

Poos,[53] in a large series of experiments using various animals, showed that the pituitary reacts qualitatively in the same way when other glands of internal secretion are disturbed by experimental attack. The quantitative differences are dependent upon the severity of the endocrine changes produced and secondarily, upon the length of the experiment. He differentiated four

stages of reaction processes affecting the pituitary after adrenalectomy: (1) the stage of increased physiologic reaction; (2) the stage of pituitary hydrops; (3) the stage of degeneration; (4) the stage of pigment formation. Much, therefore, depends upon the stage when the pituitary is examined after adrenalectomy. If examined soon after operation the gland will be found in the stage of increased physiologic reaction, whereas in later development it will show the stage of degeneration. Thus one can reconcile the opposite views of the two groups.

Infantilism is usually associated with a pituitary disturbance and, as Wolf[68] said, all cases of infantilism have some degree of pituitary involvement, whatever the ulterior cause of the retardation may be. The tissues are usually poorly developed, showing itself in an infantile type of heart and narrowness of the circulatory system. It is evident that a normal or near normal development of this system is essential to growth.

As previously stated, it seems quite likely that the chromophil cells of the pituitary, the eosinophil and basophil, are synergistic in action and the adenomas of these cells have certain symptoms and findings in common. Both types have the ability to produce an increased blood volume and hemopoiesis but only the eosinophil hyperplasia or adenoma causes bodily overgrowth such as acromegaly and gigantism. It is a foregone conclusion, however, if the hypothesis is correct, that the basophil cells participate in these diseases in order to bring about hemopoiesis. The increase in size of an extremity by vascular formation and an increased oxygen saturation above normal are seen in arteriovenous fistula. This is supportive evidence that growth as seen in pituitary overactivity is produced in this manner. The growth of youthful individuals suffering from hyperthyroidism is well known. Holmgren,[19] for instance, showed that these patients grew faster than normal, that is attain their adult growth faster than normal. The height they reach is, of course, dependent to a great extent upon hereditary and constitutional factors. In hyperthyroidism the circulating blood volume is much increased and the oxygen consumption is greater than normal as shown by the increased metabolic rate. The vascular system of the growing individual increases in extent.

The state of the pituitary in hyperthyroidism has been reviewed elsewhere and the majority opinion seems to be that in this disease the pituitary is overactive; hyperemia of this gland is usually present.[45]

That there is an increased functional activity of the neighboring hypothalamic area is most likely in view of the symptoms seen in hyperthyroidism. Another disease showing the pituitary-vascular-hemopoietic system relationship is hypertrophic pulmonary osteoarthropathy. Changes in the pituitary have been described in this disease. Fried,[12] for instance, reported 4 cases of pulmonary osteoarthropathy associated with bronchiogenic cancer in which evidence was presented to show that the condition is, in all likelihood, caused by an endocrine imbalance (dyspituitarism). All 4 patients had bronchiogenic cancer and symptoms of acromegaly. Three came to autopsy and revealed hyperplasia of the eosinophil cells of the pituitary. The fourth case was not autopsied but had acromegaly.

It was shown by the sequence of events in the history and findings that the bronchiogenic cancer antedated the acromegaly for as Fried said "apparently the osteoarthropathy reached considerable dimensions when the neoplasm was still small." It is reasonable to suppose that the pituitary eosinophil cell hyperplasia was secondary to the bronchiogenic cancer and the former caused the osteoarthropathy and acromegaly.

Fried dismissed the theory that a toxin causes the glandular changes in osteoarthropathy. Locke,[35] in an extensive review of chronic pulmonary hypertrophic osteoarthropathy, found that acromegaly is so closely related to the former condition that some authors, whose cases were re-

viewed, reported them to be pulmonary osteoarthropathy. He was of the opinion that the changes in the skeleton in a well developed case of secondary hypertrophic osteoarthropathy are seldom confined to the bones of the forearm, hands, lower legs and feet as so often described. He suggested that the bone changes were similar or identical with the appearances of acromegaly. He showed that the bone changes were not confined to the diaphyses, but all well established cases showed a very marked new formation of bone in the epiphyseal portion. The marrow showed various changes and was often embryonic. This is like the change seen in polycythemia associated with an adrenal cortex tumor and

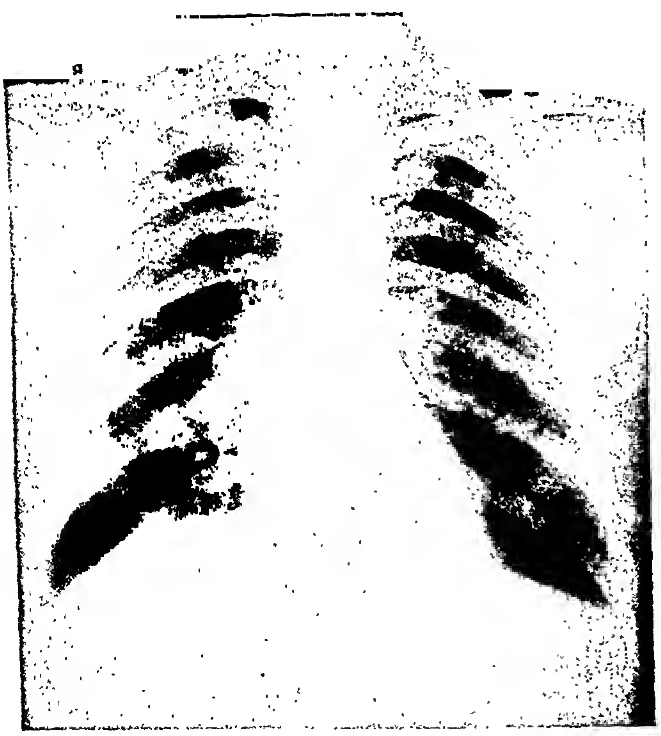

Fig. 2. Roentgenogram of chest showing infiltrative lesion of right lung producing clubbing of fingers. (Chronic pulmonary osteoarthropathy.)

lung metastases. The periosteum is thick and vascular. The tissues are thickened and the capillaries are dilated. Illustrative of these findings is the following brief summary of a case.*†

* I wish to thank Dr. Louis Carbone for permission to report this case.

† This patient has since died and the postmortem showed a bronchiogenic carcinoma. Unfortunately permission for postmortem of the head could not be obtained.

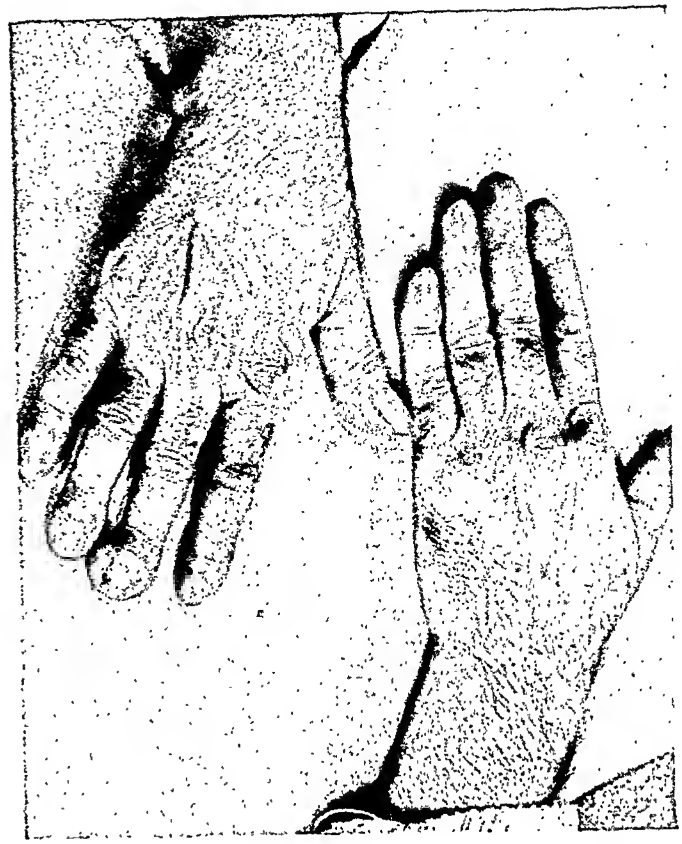

Fig. 3. Clubbing of the fingers. The enlargement of the third finger distal phalanx is due to trauma and clubbing.

An Italian laborer, aged sixty-one, was seen on April 26, 1945, with dyspnea, cough, and swelling of the fingers and toes. Symptoms were of four months' duration. Roentgenograms of the chest revealed an infiltrative type of lesion in the area of the right lobe (Fig. 2). The lesion had been increasing in size and a biopsy obtained by bronchoscopy showed merely chronic inflammatory changes. Clubbing of the fingers was present. The third finger of the right hand showed a marked enlargement of the distal phalanx due to an old injury as well as to the clubbing (Fig. 3). The toes also showed clubbing but to a lesser degree. The femur, tibia and fibula showed marked proliferative changes of the periosteum (Fig. 4 and 5). The hemoglobin was 82 per cent (Sahli) and the red cell count was 4,080,000 and the leukocyte count 11,000. The glucose tolerance test was: fasting sugar 103 mg. per 100 cc.; $\frac{3}{4}$ hour—180 mg.; $1\frac{1}{2}$ hour—185 mg.; $2\frac{1}{2}$ hour—180 mg. The disease is a progressive one and we feel certain that it is due to a neoplasm of the lung despite the unsatisfactory biopsy report.

This case illustrates the marked clubbing of the fingers and toes characteristic of chronic pulmonary osteoarthropathy due

Fig. 4. Bony overgrowth of femur, tibia and fibula. Sclerosis of patella is well shown. (Chronic pulmonary osteoarthropathy.)

to a lesion of the lung, apparently a carcinoma. The marked proliferation of the periosteum of the long bones is an outstanding feature of the roentgenograms. As has been shown, the thickened periosteum is very vascular with dilated capillaries and is strong supportive evidence that the chromophil hyperplasia of the pituitary is responsible for these changes.

The lessened glucose tolerance is also probably due to the same pituitary changes.

Eosinophil cell hyperplasia of the pituitary would, as postulated in the article, be responsible for the vascular changes. As shown, these cells are most frequently hyperplastic in chronic pulmonary osteoarthropathy but the basophils no doubt also participate in the disease.

The close association between acromegaly and hypertrophic pulmonary osteoarthropathy has been recognized for many years. Packard[51] discussed this relationship at an early date (1892). Field,[11] Jolly,[29] Murray[49] and Thayer[63] are just a few who have reported on this association.

Locke[38] reported a case with hyperplasia of the pituitary chromophil cells associated with primary carcinoma of the lung. Benda[5] reported an interesting case that had hyperplasia of the pituitary basophil cells and a diminution of the eosinophils. He termed his case "pseudo-acromegaly." This is of interest in that we usually find eosinophil cell hyperplasia or adenoma formation in association with acromegaly or the acromegaloid findings of pulmonary osteoarthropathy. It has been stated that the chromophil cells must be closely related physiologically and chemically, and their anatomical juxtaposition make this seem likely. The chromophobe cells are supposed to be the mother cells of the chromophil cells.

Since hyperplasia of the pituitary chromophil cells is associated with primary carcinoma of the lung, it is of interest that the pituitary shows histological changes in cancerous patients. Houssay[21–27] stated that there has been found an "increase in the principal cells, increase or decrease of

Fig. 5. Anteroposterior view of femur, tibia and fibula showing bony overgrowth associated with chronic pulmonary osteoarthropathy.

the basophils, increase in the weight of the gland and in the number of eosinophils, signs of hyperactivity of the anterior lobe, and hypoactivity of the posterior. In rats with subcutaneous implantation of tumors, there is an increase and vacuolization of the basophil cells of the pituitary, with enlargement of their Golgi apparatus. The changes are similar to those produced by castration; although the sexual cycle is not affected. If these pituitary glands are then implanted into immature rats, it can be demonstrated that they have an increased gonadotrophic activity. If the cancerous implantation is made into the uterus there is a larger increase of the eosinophil cells of the pituitary and less of the basophiles and the pituitary appears like that of pregnancy or after the injection of estrin."

Kraus[35] described the hyperplastic changes in the pituitary in various diseases, such as in athyreosis and hypothyreosis. In these diseases he described a special cell which he termed "Kraus' thyroprival cell." With reference to the changes in the pituitary in malignancy he also described hyperplastic changes. He stated that both carcinoma and sarcoma produced hyperplastic changes in the anterior lobe. However, the reports in the literature are not all uniform. Kraus explained the differences as follows: "The dependence of the cytological picture in the anterior lobe upon various factors, such as age, state of gonads, obesity, contracted kidneys, hypertension, etc., makes it conceivable that in cases of carcinoma or sarcoma these factors may influence the changes produced by the malignant tumor."

These findings in cancerous patients are of great significance. It would seem, therefore, that the pituitary changes are not specific for cancer of the lung. However, there is no discounting the fact that in pulmonary osteoarthropathy without cancer of the lung there are pituitary changes. One is forced to the conclusion that primary lung changes result in secondary pituitary chromophil cell hyperplasia.

The possibility exists that a neoplasm of the lung activates the chromophil cells by two methods: first, as we have seen, the presence of cancer results in chromophil changes in the pituitary and second, its location in the lung induces further activation of these cells. The fact that the bone changes in pulmonary osteoarthropathy are like those found in acromegaly lends support to the view that the pituitary is responsible for the osseous changes. Other lung and cardiac conditions produce clubbing of fingers and toes but there is no acromegaly or polycythemia. Particularly does bronchiectasis produce clubbing. This is probably circulatory in origin with stasis in the periphery like that seen in arteriovenous fistula.

The osseous changes in the fingers as seen in pulmonary osteoarthropathy again indicate that an increased blood supply is responsible for the bony overgrowth. One can hardly escape the conclusion that the increased blood supply to the tissues induced by pituitary-eosinophil hyperplasia or adenoma formation is the direct cause of acromegaly and gigantism with the clinical manifestation of osseous and visceral overgrowth.

It seems likely that the capillary system and the hemopoietic system with the varying rate of oxygenation in these systems as well as the speed of the circulating blood volume will affect the development and function of all the endocrine glands. Such an effect readily explains why the term "master gland" is applied to the pituitary.

The close relationship existing between the pituitary and the vascular hemopoietic system is further illustrated by the pharmacological effect of the posterior pituitary lobe extract on certain *mesodermal* derivatives. These are: a vasoconstrictor effect on the capillary vascular systems; an antidiuretic effect on the renal tubules and glomeruli; a stimulating effect on the pigment cells of the frog; a constricting effect on the smooth muscles such as the uterus, intestines and bladder.

That the posterior lobe maintains capillary tone is shown by the work of Krogh.[36]

This investigator found that a few hours after complete extirpation of the pituitary in the toad, the capillaries and arterioles of the skin became dilated. Injection or perfusion of posterior lobe extract (pituitrin) even in doses of 1:1,000,000 re-established the capillary tone. Larger doses produced a contraction of the arterioles as well. From these facts he concluded that the pituitary, by means of a hormone, had a continuous action of the tone of the capillaries.

It would seem, therefore, that the data support the contention that the pituitary gland as a whole is important to the vascular system.

As is known, the anterior lobe produces changes in the adrenal cortex but the posterior lobe also does so. Osius and I[48] injected rabbits with posterior lobe extract (pituitrin) for one hundred days. The average adrenal weights of the normal control rabbits was 278 mg. while that of the injected group was 415 mg. The microscopic examination revealed that the increase of the adrenals was confined to the cortex. In addition to this, we produced arteriosclerotic changes in rabbits' arteries by injecting posterior lobe extract and feeding large doses of cholesterol containing substances (lanolin and cotton seed oil).

Hypophysectomy in rats having mammary gland carcinoma resulted in slowing the rate of growth of the transplants in hypophysectomized rats. These findings suggest that the tumors growing in the hypophysectomized rats were less adequately vascularized than those growing in normal rats (literature by Van Dyke[64]). The lessening of the vascularization bears out the opinion that growth is dependent upon a normal pituitary maintaining a normal blood supply. Naturally, growth is slowed by this process. It is an incontestable fact that no matter how adequate the diet may be in hypophysectomized animals, they will not grow unless growth promoting hormone is also administered. It is of some significance that there is an increased amount of water in the animals receiving growth extract. This, as well as an increase in the protein or total nitrogen in the tissues of animals injected with growth extract, indicates that these elements are necessary for growth. It has also been shown that tumor growth parallels body growth to some extent (Van Dyke).

From the known facts that a cancer produces hyperplastic changes in the pituitary and that pulmonary osteoarthropathy is also associated with similar pituitary changes certain suggestive speculations are permissible. For instance, one might be tempted to suggest that an embryonic type of tissue in the lung, such as a cancer, might produce a reaction in the pituitary. This would, of course, be specific for lung tissue, but the disease, pulmonary osteoarthropathy, is also associated with chronic purulent conditions of the lungs. Is the location of the neoplasm in the lung or the chronic purulent condition of the lung (even though involving a small amount of pulmonary tissue) sufficient to stimulate the pituitary changes? Is there enough change in the lung to interfere with the vital function of oxygenation? From the size of the lesions the latter would hardly be the answer. One may ask another question, does the growing neoplasm or the purulent lung disease cause an inflammatory reaction that calls for vascularization, oxygenation, and hemopoiesis and this process in turn result in a compensatory hyperplasia of the pituitary cells? This seems to be the logical explanation. The pituitary stimulates the development of the lung tissue. Not only do we see this in the human suffering from acromegaly and gigantism but it is also seen in the animal made acromegalic by crude pituitary beef extract as shown by Putnam, Benedict and Teel.[51] Their report on the lungs follows: "The lungs were engorged, purple and soft, but not crepitant; they sank in water. Pink foam could be squeezed from the bronchi and from the cut surface. In the control animal, the lungs were pink, dry and crepitant. There were no areas of consolidation in either animal. In the experimental animal, the lungs

weighed 545 gm.; in the control animal, 160 gm."

The microscopic report on the lungs read: "There was a congestive edema of the lungs of the treated animal. Most of the alveoli were filled with an amorphous protein precipitate containing a few red cells. A few were distended with air. There was no bronchitis, and no purulent or fibrinous inflammation. The capillaries were congested. By comparison the normal lung appeared particularly empty and delicate. There was no striking difference in the general size of the alveoli between the two lungs." They went on to say, "The factor of long-standing congestion must be taken into account in some of these organs, particularly the lungs, which were edematous, *but obviously cannot explain the full extent of the changes.* Of interest is the fact that there was great engorgement of vessels everywhere in the experimental dog. The weight of the heart was double that of the control dog."

Stockard and Vicari[61] studied the pituitary glands from 8 male and 6 female bulldogs. Microscopically, while they were not uniformly alike in detail, their general qualities were closely similar. The features were constant enough to enable one to distinguish the bulldog pituitary from that of the long muzzled breeds. The chromophilic proportions of high acidophilic and low basophilic cells were characteristic of the bulldog gland. There were more than thirty acidophilic cells to one basophilic.

Stockard and Johnson[60] in studying dogs, crossed various species, said that, "The one character common to all these breeds and hybrids in which structural misfits occur is an abnormality of the pituitary gland. Such an array of growth disharmonies in association with pituitary abnormality makes it seem highly probable that the pituitary secretions are largely concerned with the normal regulation and adjustment of growth among the organ systems and bodily parts. It should be remembered that many of these disharmonious arrangements are strictly inherited in very definite fashion. This fact may mean that the related peculiarity of the pituitary is the primarily inherited character, while the structural derangements are secondary results due to the failure in harmonious growth regulation by the genetically modified pituitary gland." It would seem most likely, therefore, that the inheritance factors carried in the genes would determine how a particular tissue or organ would develop in the uterus and post-fetal life, reacting to the pituitary secretion according to this inheritance factor. Thus one can understand the somewhat varying clinical picture seen at times in acromegaly and gigantism as well as in other pituitary diseases.

As Kenyon[30] said, while much is known of the pituitary relationship to the adrenal cortex, the reverse, that is, adrenal cortex changes followed by pituitary changes, is not. Some of the data relative to this have been given. That an adrenal cortex tumor with metastases to the lung may result in pituitary changes is shown in a brief summary of a case previously reported:[47]

A white laborer, aged sixty-three, had a left inguinal hernia repaired and a left hydrocele excised. A month later he returned complaining of vomiting and loss of weight. A hard irregular mass about 7 cm. in diameter, extending downward from the left costal margin, was present. Roentgenograms of the lungs showed evidence of pulmonary metastases.

The average values found in the patient's blood may be summarized as follows: red blood cells, 8,194,000; hemoglobin, 153 per cent; reticulocytes, 1.3 per cent; polymorphonuclears, 95 per cent; lymphocytes, 5 per cent, and white blood cells, 8,000.

At postmortem examination a large invasive tumor of the left kidney was found. This had metastasized to the lungs. Microscopically, the tumor was found to be a malignant angiomesothelioma with large pale staining cells. The structure was different from the ordinary type of Grawitz tumor and in some areas was markedly reminiscent of decidual tissue. The pituitary was not remarkable grossly but microscopically showed marked hypertrophy and hyperplasia of the basophil elements. The bone marrow showed marked myeloid hyperplasia throughout the marrow space.

Fig. 6. Massive portal thrombosis associated with polycythemia.

The embryonic type of tumor resembling decidual tissue, involving the adrenal cortex and metastasizing to the lungs, produced a pituitary basophil hyperplasia and a resulting polycythemia vera and a marked hyperhemoglobinemia.

Another case observed at Harper Hospital of polycythemia vera with pituitary basophil hyperplasia is reported, as follows:

M. S., white male, aged forty-five; height, 74 inches; weight, 220 pounds. Complained on admission to the hospital, January 5, 1945, of pruritus ani and rectal bleeding for one year. Treated for peptic ulcer four years ago. For the past eight months numbness and tingling of the left calf while sitting. Gave ten blood transfusion donations to the Red Cross before hemorrhoidectomy. Important findings at that time were: hemoglobin, 107 per cent; erythrocytes, 5,900,000; leukocytes, 10,900; differential count, normal. Had a hemorrhoidectomy, fissurectomy, sphincterotomy, and circumanal neurotomy and was discharged on January 10, 1945, Re-admitted January 17 for sudden severe lower abdominal pain. Patient was cold, clammy and in a state of collapse. The hemoglobin was 136 per cent, red blood cells 7,000,000, white blood cells 25,800, 86 per cent polymorphonuclears; nitrogen 77 mg. per 100 cc. of blood, icteric index 11, total protein 6.2. The abdominal distention became marked with some rigidity; the liver was palpable. He passed blood clots in the urine and he became cyanotic, irrational and died on January 25, 1945. Postmortem: The important findings on postmortem examination were a massive portal thrombosis (Fig. 6), thrombosis of the splenic vein (Fig. 7), and basophilia of the pituitary gland (Fig. 8). This relationship of the pituitary basophilia to the polycythemia is of importance and is further evidence that the basophil cell is related to erythropoiesis.

Adams and his associates[1] reported a case of hemangioma of the lung, with clubbing of the fingers and toes and generalized

Fig. 7. Thrombosis of the splenic vein associated with polycythemia.

cyanosis. The roentgenogram of the chest revealed a large, irregularly shaped, circunscribed opacity in the left lung and a small one in the right lung. There were associated compensatory polyemia, polycythemia and hyperhemoglobinemia. The authors said that on the basis of the pathologic picture the lesions are really arteriovenous aneurysms or fistulas. The pulmonary lesion produced a great compensatory change in the quality and the quantity of the blood. Polycythemia (7,200,000 red cells) was present before the operation and was reduced by this procedure. The microscopic study of the specimen removed from the lung revealed pulmonary tissue surrounding the three separate mesothelial lined cavities found in the left lung. The writers stated that the condition in others has probably gone undiagnosed and has been treated as polycythemia vera.

In view of the relationship of the pituitary to blood formation, the vascular system, and oxygenation, it is unfortunate that studies of the pituitary are not included as a routine in conditions involving these functions.

A close relationship exists between the lung with its capillary surface area, oxygenation, circulating blood volume, volume of respiratory exchange and the functions of the pituitary gland. Certain it is that if this gland is concerned with the formation of capillaries and the circulatory system and with hemopoiesis, then there must be an unquestioned interrelationship between lung function and the pituitary.

The proved fact that the pituitary is concerned with water exchange in the kidneys immediately suggests in view of the foregoing that it is also concerned with the insensible water loss of the lungs brought about by the water discharged through these organs. Respiration, as we know, involves a continuous loss of water from the body and as physiologists have shown the amount lost varies directly with the difference in temperature between the subject and his environmental air and inversely as the vapor pressure of the latter.

We are also acquainted with the fact that temperature regulation is a function of the hypothalamus, demonstrating the close physiological connection between the pituitary and hypothalamic functions.

The recent work on thiouracil and its effect on the thyroid and pituitary glands is of interest in the present discussion of growth. Griesbach[15] showed that rats treated with brassica seeds had changes in the pituitary consisting of a rapid increase in the basophilic cells and a decrease in the

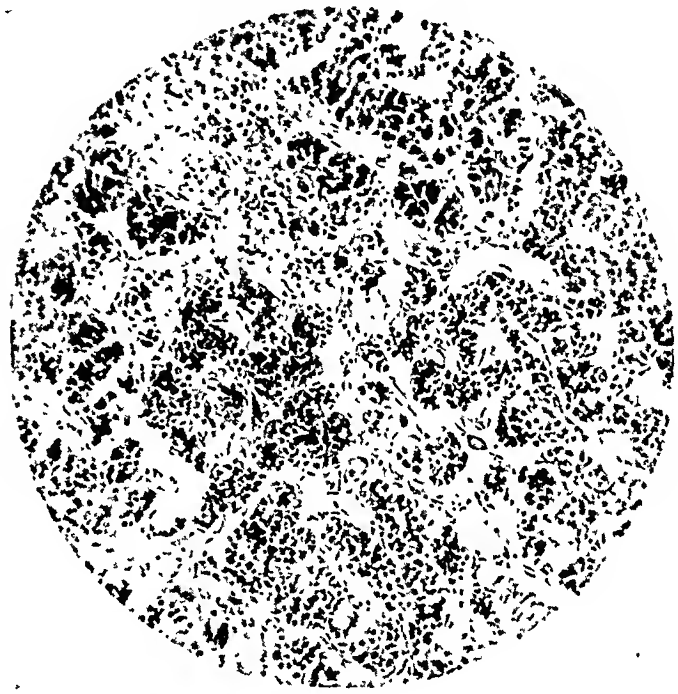

Fig. 8. Basophilia of the pituitary gland associated with polycythemia.

acidophilic. No goitrogenic effect was seen in rats previously subjected to hypophysectomy. He stated that this indicates that in order "to produce thyroid hyperplasia it requires the mediation of the thyrotropic hormone of the pituitary." The rate of growth was inhibited when young animals are fed thiouracil, thiourea and sulfonamide compounds. This is readily understood since the eosinophil cells are reduced in number. Furthermore, thiouracil inhibits the growth-promoting effects of anterior pituitary growth hormone injected into rats. Cretinism is produced in these animals by thiourea and thiouracil (Hughes[28]). The thyroid glands of the animals so treated show within a few days a distinct enlarge-

ment. Astwood and Bissell[2] found that seventy-two hours after thiouracil therapy was begun on rats there was a 60 per cent increase in weight of the thyroid gland. The enlarged thyroid glands were vascular, the cells being tall and columnar with a reduction in the colloid.

Sulfonamide compounds and thiourea produced changes in the pituitary gland. These were degranulation and decrease in number of acidophil vacuolation and increase in number and size of the basophils (MacKenzie and MacKenzie[40]). The effects were similar to those seen after thyroidectomy. It is interesting in this connection that Poos' experiments indicate that no matter which endocrine gland is removed the pituitary goes through four stages of reaction and if these changes are similar to those following thyroidectomy then one can understand that increased vascularity would be the result of the initial stage of physiological overactivity of the pituitary gland followed by the stage of degeneration. The increase in acidophils would account for the stage of increased vascularity.

If the eosinophil and basophil cells are reduced in function then it is readily understood why growth is inhibited and anemia of a severe degree may ensue even to the extent of agranulocytosis. No doubt the whole reticulo-endothelial system is depressed.

It is of interest and pertinent to the present discussion that Schittenhelm and Eisler[57,58] found that there was a local increase of thyroxin-iodine in the interbrain by the experimental exhibition of this latter substance when given to rabbits. These investigators injected rabbits intravenously for ten days; a daily dose of thyroxin equal to 1 mg. per kg. of body weight was given. The thyroxin had a selective action for the interbrain.

Sturm and Schneeberg[62] found after a single intravenous injection of thyroid and iodine feeding of rabbits values in the tuber cinerum of 260 gamma and 560 gamma of iodine and in the pituitary between 700 and 2,400 gamma of iodine. According to Lohr and Wilmanns[39] the various sections of the brain contain normally between 5 and 35 gamma of iodine. The human pituitary contains 60 gamma of iodine. This was the average of 24 pituitary glands. The highest values are, therefore, found in the pituitary and this coupled with the fact that pituitary tissue was the most active one in destroying thiouracil points to a certain common denominator in achieving benefits in thyroid disease when these drugs are administered.

Some of the benefits obtained by iodine are unquestionably due to its central action.

It is certain that many symptoms of thyrotoxicosis are due to central nervous system involvement. The benefits of iodine administration in this disease may therefore be similar to thiouracil in its action on the pituitary and interbrain.

The lessened response to thiouracil in patients who have received iodine may have an explanation in that the iodine is probably not so easily displaced in the pituitary and interbrain because of the affinity of these for iodine and the thiouracil by-passes the pituitary. In other words, there is a chemical affinity of the iodine for pituitary tissue.

Gordon, Goldsmith and Charipper[11] showed that feeding of thiourea or sulfadiazine to rats for fourteen or forty-five days caused a diminution in the quantity of thyroid-stimulating factor in the blood sera and pituitary glands as judged by the effects of such materials on the rate of metamorphosis of *Rana pipiens* larvae. Rats six months after thyroidectomy possess increased amounts of thyrotrophic hormone in their blood sera and hypophyses.

The above authors conclude that these materials depress the formation of active thyroid principle and cause an increased release of thyrotrophin from the pituitary into the blood, where, however, it appears in reduced amount because of its removal and increased utilization by the enlarging thyroid gland.

Rawson, Tannheimer and Peacock[54]

found that the average uptake of radioactive iodine by the control rat thyroids was 56 per cent of the administered tracer dose, that by thyroids of thiocyanate treated rats, 87 per cent and that by thiouracil treated rats, 10 per cent. These writers state that "it appears then that at least one action of this drug [thiouracil] on the function of the thyroid is to interfere with the iodinization of the thyroglobulin molecule, thus preventing the elaboration of any physiologically active hormone."

Astwood and Bissell[2] found that the administration of thiouracil to young rats was followed by a nearly complete disappearance of iodine from the thyroid glands in five days and a threefold increase in the size of the glands in two weeks. These effects were inhibited by hypophysectomy or by the injection of thyroxin. Injections of thyroxin or removal of the pituitary markedly retarded the accumulation of iodine.

Of importance are the anatomical effects of thiouracil. Williams, Weinglass, Bissell and Peters[67] studied the anatomical effects of thiouracil on rats and found among other things that thiouracil caused a distinct retardation in the rate of growth. It also tends to abolish the effects of growth hormone. The pituitary, adrenals and gonads of thiouracil treated animals were smaller than those of the siblings. A few animals showed a distinct leukopenia and anemia. Six patients who were given thiouracil for six to twenty-eight days preceding death were not found on postmortem examination to show any gross or microscopic effects of this drug.

To be valid, however, it would be necessary to study the pituitary glands of animals having agranulocytosis, but even in these rats the pituitaries were smaller and no doubt had a reduced function. As noted, some showed leukopenia and anemia.

Concerning the 6 human subjects, only 0.6 gm. daily was given for too short a time to draw any conclusions. The study of the pituitary gland in fatal agranulocytosis is necessary.

Certain immune mechanisms can be postulated as being at work. If the pituitary has a hemopoietic function, then whenever fever is present such as seen in infectious processes it is reasonable to assume that the latter sets the hypothalamic-pituitary mechanism in motion with resulting increased circulating blood volume, oxygenation and hemopoiesis including leukocytosis. It will be remembered that in Cushing's syndrome leukocytosis is present *without* infection, showing that the basophil cells play a part in the immune mechanism of the body.

One can also understand why severe or long standing infections by their toxemia may depress the pituitary function and lead to severe anemia and death.

Kraus and Traube[34] found the number of basophil cells reduced in individuals with asthenic habitus such as in tuberculous individuals and if these cells have anything to do with the immune mechanism it is logical to suppose that they would react poorly to infection. Understandable on this basis is the fact that a hypoplastic pituitary would react poorly to lung involvement or any infection.

A study of the immune mechanism reveals the fact that practically all the elements involved in immunity are derivatives of the mesoderm. The pituitary has a selective action on the mesoderm and if such is the case then hypoplasia of the pituitary during intrauterine life would result in an asthenic habitus with hypoplasia of the mesoderm.

Perla[52] concluded from his work that hypophysectomy is associated with a drop in natural resistance to spontaneous bacterial infections and to induced infections with a protozoan such as *Trypanosoma lewisi*. Decrease in resistance to such infections is in part due to atrophy of the spleen and lymphoid tissue of the body. Perla is of the opinion that the drop in natural resistance, particularly to poisons following the removal of the pituitary, is in part an expression of the insufficiency of the function of the suprarenal cortex, due to the withdrawal of the adrenotrophic hormone.

There has also been demonstrated a definite relationship of the pituitary to the spleen. Decrease in size of the spleen follows hypophysectomy. There is a progressive atrophy of the spleen following this operation (Perla).

White and Dougherty,[56] from their experimental work, stated that "The data lead to the conclusion that the lymphocytes of lymphoid tissue are a storehouse for a portion of the globulin fraction of the serum, and that the rate of release of this protein is under the normal physiological control of the pituitary adrenotrophic hormone which exerts its influence by way of the adrenal cortex. The evidence permits the integration of the functioning of the lymphocyte and the adrenal cortex in normal defense mechanisms of the organism."

In connection with the statement that the rate of release of globulin protein is under the control of the pituitary, the work of Leathem[37] becomes of interest. This worker found that a rise in total plasma protein concentration occurs in male rats fed 1 per cent thiourea for twenty to twenty-two days. This total protein rise is due entirely to an increase in plasma globulin, in that plasma albumin concentration does not change. Thus the blood protein changes simulate those observed after thyroidectomy.

A study of the literature emphasizes the importance of the pituitary to the immune mechanism of the body. It is logical to assume that the relationship of the pituitary to the development of the vascular system (including the capillaries), hemopoiesis, oxygenation and lung function places it in the front ranks of the factors controlling immunity. As previously stated, infection and any modality which induces fever will involve the hypopthalamic-hypophyseal system which activates the immune mechanism.

On certain occasions, though not too frequently, hyperpituitarism in the form of acromegaly or gigantism may follow a long standing infection such as typhoid fever. On the other hand, clinicians frequently see rapid growth in youthful individuals following an acute infection such as scarlet fever and measles. Presumably the infection activates the pituitary.

Furthermore, it is well known that the sulfonamide compounds including thiourea and thiouracil produce fever and it is reasonable to suppose it is due to the toxic effect on the hypothalamic-hypophyseal mechanism. Occasionally, as reported by Cargill and Lesses,[7] submaxillary gland swelling follows the administration of thiouracil. This, we believe, is due to the changes in the thyroid for it has been shown that the thyroid is essential to the development of the salivary glands (Hammett[16]).

It is interesting that iodides not infrequently cause swelling of the submaxillary glands as well as salivation.

F. D. Dodrill and I are reporting the results of our experiments on dogs showing the reciprocal relationship between lung function and the pituitary gland. Dogs normally have a polycythemia (6 to 7 million red cells per 100 cc.) compared to humans. These animals do not have sweat glands and the rapid oxygen exchange with panting explains why they normally have a comparative polycythemia as compared to humans. They also have large spleens.

SUMMARY

Clinical evidence has been presented to show that the pituitary gland produces growth by the formation of the mesodermal vascular system and by supplying blood to the tissues. The production of localized acromegaly or gigantism has been seen in arteriovenous fistula of an extremity showing that it is by an increase in the vascular development with consequent increase in blood supply that growth takes place. In this instance there is no generalized increase of pituitary function but this example illustrates that growth may be produced by such conditions without the presence of a specialized growth hormone. *If one accepts the hypothesis that the pituitary gland in-*

duces growth by developing the circulatory system of the body and hemopoiesis, then there is no need to assume the presence of the so-called specific hormones or polyhormones since all endocrine glands would be affected by this mechanism as well as the body as a whole.

Congenital hypopituitarism results in a defective development of the vascular system with a decrease in blood supply to the tissues resulting in dwarfism.

The dwarfism of cretinism is the result of pituitary underfunction with lack of capillary development.

This same holds true for all forms of dwarfism and is responsible for the changes seen in anencephalic fetuses and renal rickets in which defective development of the pituitary is found.

A close relationship exists between the eosinophil and basophil cell of the pituitary; the former probably is responsible for vascular development and the latter for hemopoiesis.

On the basis that the chromophil cells control vascular development and hemopoiesis, and the posterior lobe has a vasoconstrictor effect on the capillaries, an explanation was offered for the phenomenon of menstruation. The menstrual function is postulated as being brought about by the activity of the anterior lobe chromophil cells producing the development of the endometrial capillaries and the endometrial blood, mediated by the synergistic estrogenic hormone with a chemical interplay between the former and the latter and then followed by the development of the corpus luteum with the antagonistic progestational hormone which holds the posterior pituitary lobe in check so that the secretory nidational endometrium is formed. If no gestation has taken place the corpus luteum degenerates, the posterior lobe hormone acts as a vasoconstrictor on the capillaries and produces necrosis and anoxia of the endometrium with consequent shedding and the phenomenon of uterine bleeding per vagina.

Primary disease of the lungs, such as cancer (primary and metastatic), and chronic suppuration of the lung, and chronic pulmonary osteoarthropathy are often associated with pituitary chromophil hyperplasia.

It was suggested that the lung disease produced an inflammatory reaction which called for vascularization, oxygenation and hemopoiesis and this process in turn results in a compensatory hyperplasia of the pituitary chromophil cells. The pituitary has been shown to produce growth of lung tissue.

Hyperactivity of the pituitary has been found in patients suffering from cancer.

A close relationship exists between the posterior pituitary lobe and the vascular system as shown by its pharmacologic effect.

Sulfonamide compounds, such as thiouracil and thiourea, produce a reduction in the number of acidophils and an increase in the basophils and it was therefore suggested that growth was inhibited by the decrease of the former cells and the vascularity increased by the latter.

Iodine has been shown to have a selective action for the interbrain and pituitary and the benefits of this form of therapy may be due to its affinity for these tissues. The slower response of iodine treated patients to thiouracil may be due to the chemical affinity the pituitary and interbrain tissues have for iodine so that this substance is not readily displaced. The pituitary and lung function are intimately related on the basis of hemopoiesis, oxygenation, and water exchange. This gland as well as the hypothalamic region is probably involved in the immune mechanism of the body, and the rapid growth in children which frequently follows infectious diseases is due to the activation of the pituitary mechanism which has been set in motion by the toxemia.

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REFERENCES

1. Adams, W. E., Thornton, T. F., Jr., and Eichelberger, L. Cavernous hemangioma of lung (arteriovenous fistula): report of case with successful treatment by pneumonectomy. *Arch. Surg.*, 1944, *49*, 51–58.
2. Astwood, E. B., and Bissell, A. Effect of thiouracil on iodine content of thyroid gland. *Endocrinology*, 1944, *34*, 282–296.
3. Bader, G. B. Renal rickets. *J. Pediat.*, 1934, *4*, 368–379.
4. Barlow, D. L. Apituitarism and the anencephalic syndrome. *Brit. M. J.*, 1923, *1*, 15–16.
5. Benda. Cited by Berblinger, W. Pathologie und pathologische Morphologie der Hypophyse des Menschen. C. Kabitzsch, Leipzig, 1932.
6. Browne, F. J. Anencephalic syndrome in its relation to apituitarism. *Edinburgh M. J.*, 1920, *25*, 296.
7. Cargill, S. L., and Lesses, M. F. Toxic reactions to thiouracil. *J. Am. M. Ass.*, April 7, 1945, *127*, 890–898.
8. Covell, W. P. Quantitative study of hypophysis of human anencephalic fetus. *Am. J. Path.*, 1927, *3*, 17–28.
9. Cushing, Harvey. Personal communication.
10. Dietrich, A., and Siegmund, H. In: Handbuch der speziellen pathologischen Anatomie und Histologie. Henke, F., and Lubarsch, O., editors. J. Springer, Berlin, 1926, p. 951.
11. Field, F. A. Acromegaly and hypertrophic pulmonary osteo-arthropathy. *Brit. M. J.*, 1893, *2*, 14.
12. Fried, B. M. Chronic pulmonary osteoarthropathy; dyspituitarism as a probable cause. *Arch. Int. Med.*, 1943, *72*, 565–580.
13. Gehri, G. Gibt es bei Schilddrüsenkranken ein pathognomonisch charakterisches Kapillarbild? *Schweiz. med. Wchnschr.*, 1930, *60*, 1254–1262.
14. Gordon, A. S., Goldsmith, E. D., and Charipper, H. A. Thyrotrophic hormone content of blood sera and pituitary glands of thiourea, sulfadiazine-treated and thyroidectomized rats. *Endocrinology*, Jan., 1945, *36*, 53–61.
15. Griesbach, W. E. Studies on experimental goitre; changes in anterior pituitary of rat produced by Brassica seed diet. *Brit. J. Exper. Path.*, 1941, *22*, 245–249.
16. H[illegible], I. S. Studies of thyroid apparatus [illegible] *Am. J.* [illegible]
17. H[illegible]
18. H[illegible]
19. Hofmeister, F. Ueber den Einfluss der Basedow'schen Krankheit und kretinistischer Zustände auf das Längenwachsthum nebst einigen Gesetzen der Ossification. Metzger & Wittig, Leipzig, [illegible].
20. Horton, B. T. Hemihypertrophy of extremities associated with congenital arteriovenous fistula. *J. Am. M. Ass.*, 1932, *98*, [illegible]. Also: *Collected Papers Mayo Clinic*, W. B. Saunders Co., Philadelphia, 1933, *24*, [illegible].
21. Houssay, B. A. What we have learned from the toad concerning hypophyseal functions. *New England J. Med.*, 1936, *214*, [illegible].
22. Houssay, B. A. Hypophysis and metabolism. *New England J. Med.*, 1936, *214*, [illegible].
23. Houssay, B. A. Carbohydrate metabolism. *New England J. Med.*, 1936, *214*, [illegible].
24. Houssay, B. A. Asthenia hypophyseopriva and neuromuscular symptoms due to alterations in the pituitary. *New England J. Med.*, 1936, *214*, 1023–1032.
25. Houssay, B. A. Hypophysis and blood pressure. *New England J. Med.*, 1936, *214*, [illegible].
26. Houssay, B. A. Certain relations between parathyroids, hypophysis and pancreas. *New England J. Med.*, 1936, *214*, 1128–11[illegible].
27. Houssay, B. A. Hypophysis and resistance to intoxications, infections and tumors. *New England J. Med.*, 1936, *214*, 1177–11[illegible].
28. Hughes, A. M. Cretinism in rats induced by thiouracil. *Endocrinology*, 1944, *34*, [illegible].
29. Jolly. Ueber Akromegalie und Osteoarthropathie. *Berl. klin. Wchnschr.*, [illegible].
30. Kenyon, A. T. Adrenal cortical tumors: physiologic considerations. *Surgery*, 1944, *16*, [illegible]–232.
31. Kiyono, H. Die pathologische Anatomie der endokrinen Organe bei Anencephalie. *Virchows Arch. f. path. Anat.*, [illegible].
32. Knox, A. Anenceph[illegible]
33. Kraus, E. J. Die Hypophyse. [illegible] Hypophyse. In: Gruber, G. B. Die Morphologie der Missbildungen des Menschen und der Tiere. G. Fischer, Jena, [illegible].
34. Kraus, E. J., and [illegible]
35. Kraus, J. E. [illegible]
36. [illegible]
37. [illegible]

38. Locke, E. A. Secondary hypertrophic osteoarthropathy and its relation to simple clubfingers. *Arch. Int. Med.*, 1915, *15*, 659–713.

39. Löhr, H., and Wilmanns, H. Ueber die Verteilung des Jods im Gehirn unter normalen Bedingungen und nach Jodzuführ. *Verhandl. d. deutsch. Gesellsch. f. inn. Med., Kong.*, 1937, *49*, 293–298.

40. MacKenzie, C. G., and MacKenzie, J. B. Effect of sulfonamides and thioureas on thyroid gland and basal metabolism. *Endocrinology*, 1943, *32*, 185–209.

41. Markee, J. E. Menstruation in intraocular endometrial transplants in the rhesus monkey. Contributions to Embryology, No. 177. Carnegie Institution. 1940, *28*, 219–308.

42. Mauksch, H. Das Verhalten der Hypophyse und des Canalis craniopharyngeus in neun Fällen von Kranioschisis untersucht. *Anat. Anz.*, 1921, *54*, 248–264.

43. Mitchell, A. G. Nephrosclerosis (chronic interstitial nephritis) in childhood, with special reference to renal rickets. *Am. J. Dis. Child.*, 1930, *40*, 101–145; 345–388.

44. Moehlig, R. C. Pituitary gland and suprarenal cortex. *Arch. Int. Med.*, 1929, *44*, 339–343.

45. Moehlig, R. C. Hyperthyroidism. *Clinics*, 1943, *1*, 1115–1167.

46. Moehlig, R. C. Hypothyroidism. *Clinics*, 1943, *2*, 423–497.

47. Moehlig, R. C., and Bates, G. S. Influence of pituitary gland on erythrocyte formation. *Arch. Int. Med.*, 1933, *51*, 207–235.

48. Moehlig, R. C., and Osius, E. A. Pituitary factor in arteriosclerosis; its experimental production in rabbits. *Ann. Int. Med.*, 1930, *4*, 578–592.

49. Murray, G. R. Clinical remarks on cases of acromegaly and osteoarthropathy. *Brit. M. J.*, 1895, *1*, 293.

50. Nature's teratological experiments. Editorial. *Brit. M. J.*, 1920, *2*, 828.

51. Packard, F. A. Case of acromegaly, and illustrations of two allied conditions. *Am. J. M. Sc.*, 1892, *103*, 657–669.

52. Perla, David. The hypophysis and resistance. In: The Pituitary Gland. Association for Research in Nervous and Mental Disease. Williams & Wilkins Co., Baltimore, 1938, Chap. 27, pp. 471–499.

53. Poos, F. Genese und Deutung der Reaktionsformen der Hypophysis cerebri. *Ztschr. f. d. ges. exper. Med.*, 1927, *54*, 709–784.

54. Putnam, T. J., Benedict, E. B., and Teel, H. M. Studies in acromegaly. viii. Experimental canine acromegaly produced by injection of anterior lobe pituitary extract. *Arch. Surg.*, 1929, *18*, 1708–1736.

55. de Quervain, F., and Wegelin, C. Der endemische Kretinismus. J. Springer, Berlin, 1936.

56. Rawson, R. W., Tannheimer, J. F., and Peacock, W. Uptake of radioactive iodine by thyroids of rats made goitrous by potassium thiocyanate and by thiouracil. *Endocrinology*, 1944, *34*, 245–253.

57. Schittenhelm, A., and Eisler, B. Untersuchungen über die Wirkung des Thyroxins auf den Eiweiss-, Wasser- und Mineralstoffwechsel. *Ztschr. f. d. ges. exper. Med.*, 1928, *61*, 239–277.

58. Schittenhelm, A., and Eisler, B. Ueber die Resorption und Ausscheidung des Thyroxins beim schilddrüsengesunden, beim schilddrüseninsuffizienten und beim hyperthyreotischen Menschen. *Ztschr. f. d. ges. exper. Med.*, 1932, *80*, 580–588.

59. Starlinger, F. Die zirkulierenden Eiweisskörper beim endemischen Kretinismus. *Arch. f. klin. Chir.*, 1929, *155*, 308–323.

60. Stockard, C. R., and Johnson, A. W. The Contrasted Patterns and Modifications of Head Types and Forms in the Pure Breeds of Dogs and Their Hybrids as the Results of Genetic and Endocrinic Reactions. The Wistar Institute of Anatomy and Biology, Philadelphia, 1941, p. 149.

61. Stockard, C. R., and Vicari, E. M. Variations in Proportional Size and Modifications in Histologic Quality of Endocrine Glands in Relation to Body Types as Found among the Dog Breeds. Genetic and Endocrinic Basis for Differences in Form and Behavior. The Wistar Institute of Anatomy and Biology, Philadelphia, 1941, p. 399.

62. Sturm, A., and Schneeberg, R. Beiträge zur Kenntnis des Jodstoffwechsels; das Gehirnjod. *Ztschr. f. d. ges. exper. Med.*, 1933, *86*, 665–674.

63. Thayer, W. S. Hypertrophic pulmonary osteoarthropathy and acromegaly. *New York J. Med.*, 1896, *63*, 33.

64. Van Dyke, H. B. The Physiology and Pharmacology of the Pituitary Body. University of Chicago Press, Chicago, 1936.

65. White, A., and Dougherty, T. F. Effect of prolonged stimulation of adrenal cortex and of adrenalectomy on numbers of circulating erythrocytes and lymphocytes. *Endocrinology*, Jan., 1945, *36*, 16–23.

66. White, A., and Dougherty, T. F. Pituitary adrenotrophic hormone control of rate of release of serum globulins from lymphoid tissue. *Endocrinology*, March, 1945, *36*, 207–217.

67. Williams, R. H., Weinglass, A. R., Bissell, G. W., and Peters, J. B. Anatomical effects of thiouracil. *Endocrinology*, 1944, *34*, 317–328.

68. Wolf, William. Endocrinology in Modern Practice. W. B. Saunders Co., Philadelphia, 1936, p. 53.

AN ANALYSIS OF THE PHYSICAL FACTORS CONTROLLING THE DIAGNOSTIC QUALITY OF ROENTGEN IMAGES*

PART I. INTRODUCTION

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THE diagnostic information which may be obtained from a roentgenographic film or roentgenoscopic screen is mainly determined by the clarity or detail with which the various roentgen images are visualized. It is therefore important that one be cognizant of the several factors which control roentgen detail and clearly understand their interrelationship. Such knowledge will greatly facilitate the choice of roentgen procedures with which optimal film and screen interpretability may be achieved. Furthermore, if sufficient quantitative data be provided, one may easily evaluate the relative merits of the various roentgen methods and materials available today.

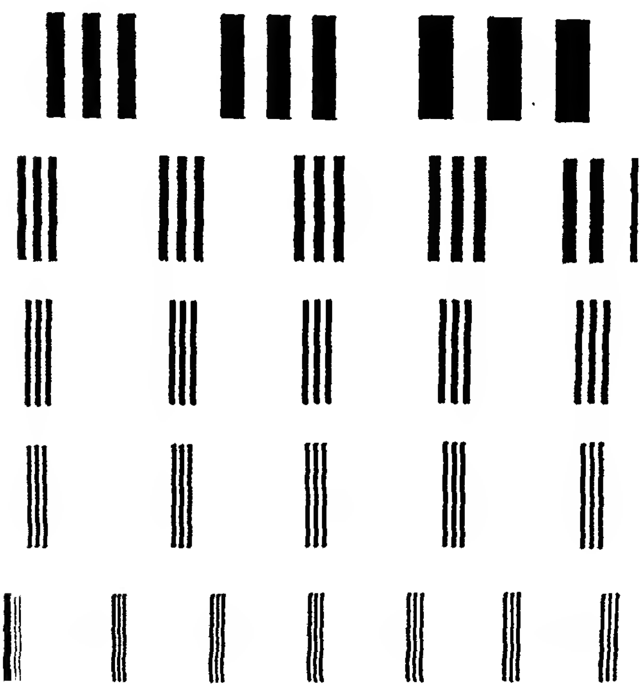

FIG. 1. Line drawing test object with which the resolving powers of photographic film may be tested.

Although the factors which control roentgen detail are generally understood, little has been written to indicate the manner in which they affect one another. In addition, a perusal of the literature reveals practically no quantitative data which are directly applicable to the solution of roentgen technical problems. It is not surprising, therefore, that opinions regarding many roentgen procedures vary between wide limits. For instance, there are many radiologists who are confident that there is an optimal kilovoltage at which each anatomical structure should be roentgenographed; others are equally certain that within reasonable limits the diagnostic quality of a roentgenogram is essentially unaffected by the kilovoltage used. A long list of similar examples could be cited. Because of this confusion a comprehensive analysis of the factors affecting the diagnostic quality of roentgen images has been undertaken and will be reported in this series of articles. It is hoped that the material to be presented will effectively clarify many perplexing problems in the field of technical roentgenology.

The clarity with which an image is recorded by a photosensitive material is a direct function of the ability of the material to record detail. This ability to record detail is customarily specified in terms of resolving power and, in photography, is measured by photographing on the film under test a line drawing similar to that

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illustrated in Figure 1. Under most circumstances films exhibit little difficulty in reproducing the coarser patterns. As one progresses to the finer configurations, however, a pattern is eventually encountered which the photographic emulsion can no longer resolve and the resultant image appears as a homogeneous opacity. The maximum number of lines per millimeter which the film can record represents the film's resolving power. The resolving powers of photographic films vary through a relatively wide range. Eastman Super XX film has a resolving power, for example, of 50 lines per millimeter whereas Eastman Microfile film has a resolving power of 130 lines per millimeter. The ability of the latter emulsion to record detail, therefore, is almost three times greater than the former.

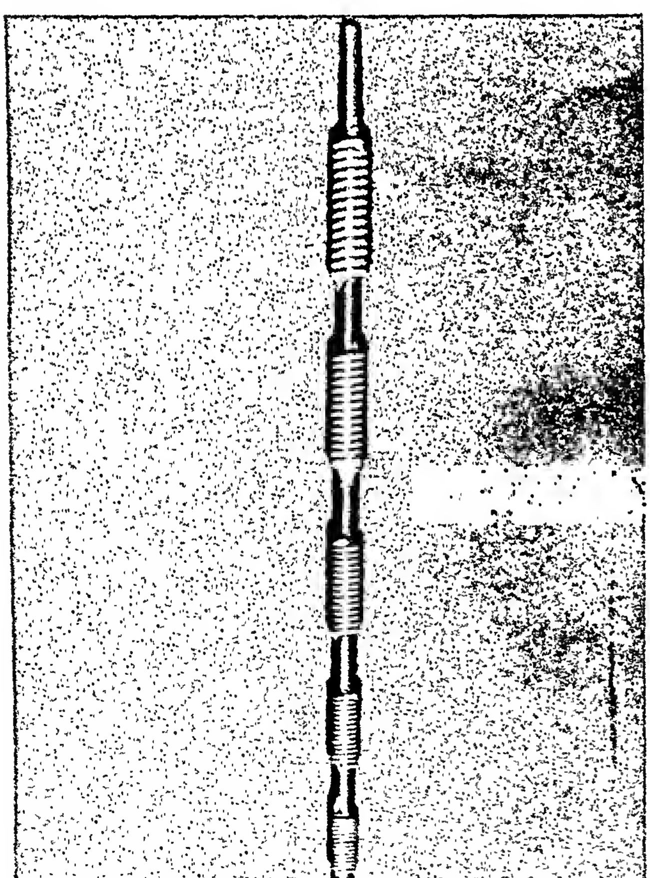

Fig. 2a. Wire-wound test object with which the resolving powers of roentgenographic films, intensifying screens and fluoroscopic screens may be measured.

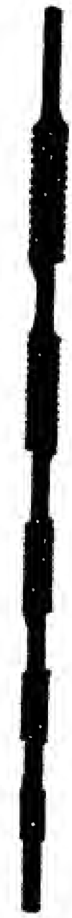

Fig. 2b. Pattern produced by wire-wound test object on roentgenographic film.

Methods for measuring the resolving powers of photographic materials[1] have become well standardized. No such order exists however in the measurement of the resolution of roentgenographic films and screens. Indeed a satisfactory method for determining the resolving powers of roentgen materials has only recently been devised. The method[2] consists of roentgenographing on the film or film-screen combination under test, a mandril on which is wound a series of wires ranging in size from very fine to very coarse. A portion of such a test object is illustrated in Figure 2a. As shown in Figure 2b, the object produces on the film a series of serrated patterns, the coarser of which the film has little difficulty in recording. As the finer configurations are approached, a pattern is eventually reached which the film is unable to resolve and the image appears

as a uniformly straight line. The maximum number of serrations per millimeter which can be clearly seen in a film constitutes the film's resolving power. A more detailed description of the method together with quantitative data on many commercially available films and film-screen combinations will be presented in Part II of this series.

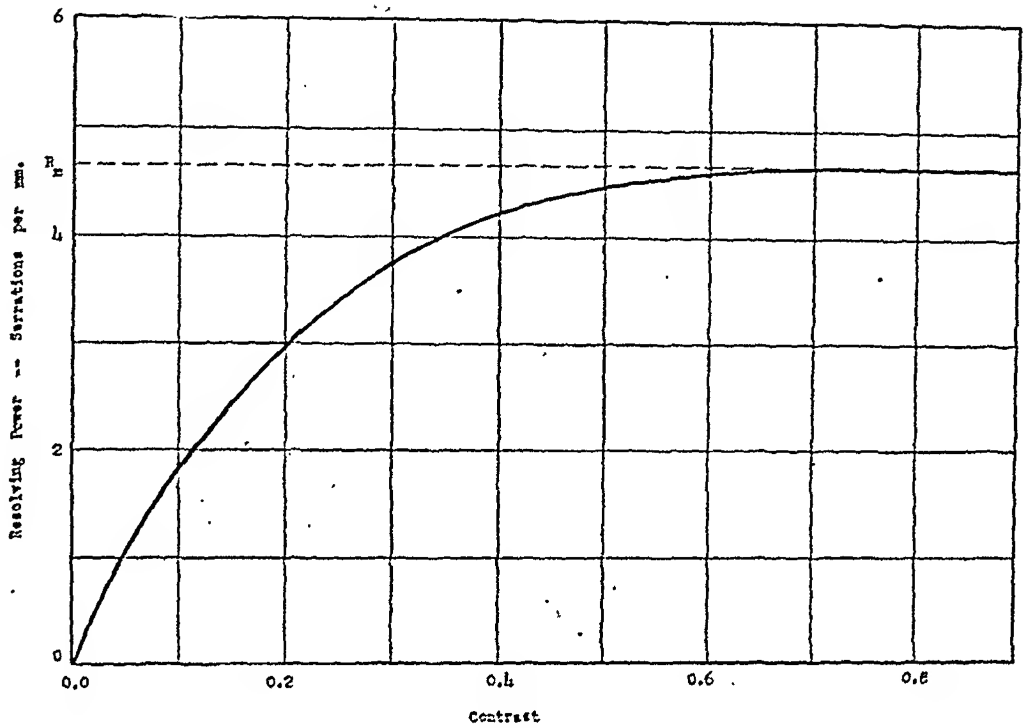

Fig. 3. Relationship between resolving power of a roentgen material and the contrast exhibited between a recorded image and its surrounding field.

The resolving power of a photosensitive material is markedly influenced by the contrast* exhibited between a recorded image and its surrounding field. This relationship is illustrated graphically in Figure 3. There it is seen that when contrast is zero, resolving power also is zero; that is, no detail can be detected under these circumstances. When contrast increases, resolving power also increases, quickly at first, then less rapidly until finally a level is reached beyond which resolving power remains relatively constant. Photographic experiments[2] indicate that this relationship is in general an exponential one† and may be expressed by the equation

$$R = R_m(1 - e^{-aC}) \qquad (1a)$$

where R is the resolving power at a level of contrast, C,

R_m is the maximum resolving power of the material

a is a constant, which may be conveniently called the resolution coefficient and

e is the Naperian base.

For images of low contrast, the relation-

* Quantitatively, the term, contrast, as used herein is defined as the difference between the logarithm of the light intensity emergent from a roentgen image and the logarithm of the light intensity emergent from the image's surrounding field; that is,

$$C = \log I_i - \log I_s \qquad (a)$$

where I_i is the intensity of the light emergent from the image and I_s is the intensity of the light emergent from the surrounding field.

Equation (a) applies to images appearing in both roentgenographic films and roentgenoscopic screens. Since the density of a roentgenographic film, according to standard definition, is equal to the logarithm of the light intensity incident on the rear face of the film minus the logarithm of the light intensity transmitted by the film (i.e., Density = log I_o − log I_t, where I_o and I_t are the incident and transmitted light intensities respectively), the contrast of a uniformly illuminated roentgenographic image may be expressed by the equation

$$C_r = D_s - D_i \qquad (b)$$

where C_r is roentgenographic contrast

D_s is the density of the film surrounding the image and

D_i is the density of the image.

† Recent experimental evidence indicates that a similar relationship obtains for roentgen materials.

ship may be more simply expressed by the equation

$$R = R_m a C. \tag{1b}$$

The value of a photosensitive material's maximum resolving power, R_m, is governed by inherent properties, such as graininess and turbidity, of the material. In the case of roentgenographic films it is also a function of image-density, developing conditions and several minor parameters. A roentgen material's maximum resolving power may be measured by means of the wire-wound test object previously described. Care must be taken of course to insure that the image produced on the film or screen exhibits a high degree of contrast.

The value of the resolution coefficient, a, is also governed in part by inherent properties of the photosensitive material. Unlike the factor, R_m, however, this coefficient has an essentially constant value for a large variety of roentgenographic films and screens.

The dependence of resolving power on contrast is particularly significant because it establishes a relationship between roentgen technique and roentgen detail. The following analysis will make this more clearly evident.

When a roentgen beam is projected through a structure, the intensity of the emergent radiation in a plane normal to the beam varies from point to point depending on the absorption which the radiation undergoes within the various portions of the structure. The emergent beam therefore presents a series of roentgen-ray images of the several components included within the structure.

The intensity of the emergent radiation at any point in the image plane is a function of a large number of variables including the thicknesses, densities and atomic numbers of the materials transmitting the radiation, the intensity of the radiation emitted by the roentgen tube and the voltage applied to the roentgen tube. Portal dimensions and filtration (including a grid, if used) also are controlling factors. The relationship between roentgen-ray intensity and the thickness and density of a homogeneous material is illustrated graphically in Figure 4. This relationship may be expressed by the equation

$$\log G = \log G_0 - \int b \rho dx \tag{2}$$

where G is the intensity of the radiation transmitted by the material,

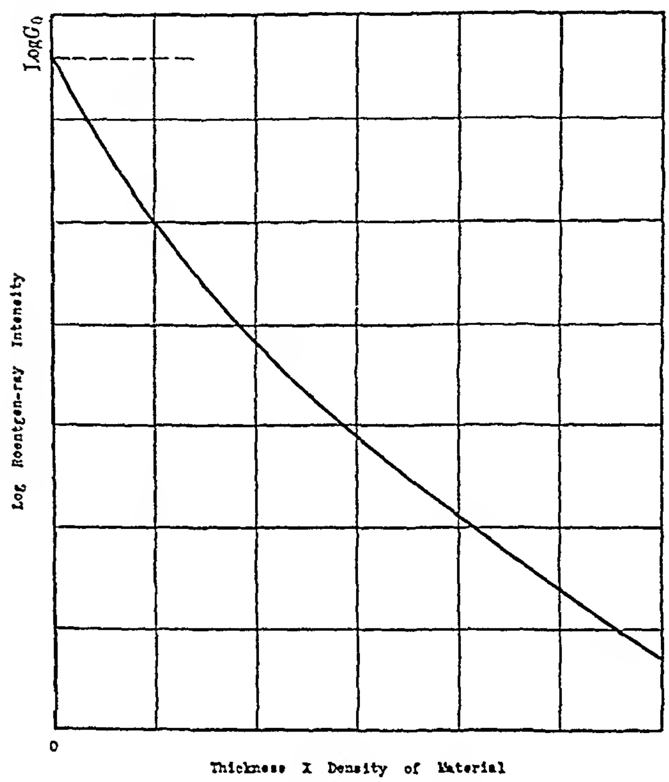

Fig. 4. Relationship between roentgen-ray intensity transmitted by a homogeneous material and the thickness and density of the material.

G_0 is the radiation intensity if no structure were interposed in the roentgen beam,

ρ and x are the density and thickness of the material respectively and

b is the negative slope of the log G vs. ρx curve.

The factor, b, is the material's mass absorption coefficient expressed in decadic logarithms. Its value is a function of the atomic numbers of the several components comprising the material and of the spectral distribution of the roentgen radiation. It thereby is a function of the voltage applied to the roentgen tube and of any filtration placed in the roentgen beam.

Equation (2) is valid only for a homogeneous structure. When the structure is heterogeneous (as is almost always the case) it may be easily shown that the equation should be written

$$\log G = \log G_0 - \int_0^{x_1} b_1\rho_1 dx - \int_0^{x_2} b_2\rho_2 dx \cdots - \int_0^{x_n} b_n\rho_n dx \qquad (3)$$

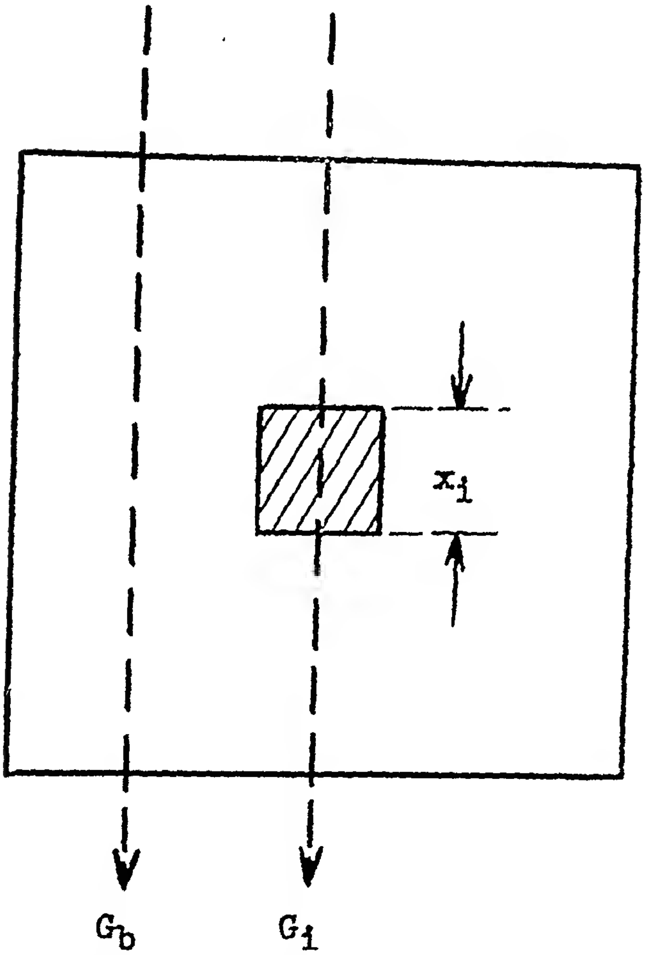

Fig. 5. Schematic diagram illustrating roentgen-ray intensities emergent from a structure below an included image-producing object (G_i) and elsewhere below the structure (G_b).

where the subscripts define the absorption coefficients, densities and thicknesses of the n materials included in the structure.

Now if a roentgen beam is projected through a heterogeneous structure which includes an image-producing object of thickness, x_i, and density, ρ_i, and having a mass absorption coefficient, b_i, the roentgen-ray intensity of the emergent beam directly below the object (see Fig. 5) is given by the equation

$$\log G_i = \log G_0 - \int_0^{x_1} b_1\rho_1 dx - \int_0^{x_2} b_2\rho_2 dx \cdots - \int_0^{x_i} b_i\rho_i dx \cdots - \int_0^{x_n} b_n\rho_n dx. \qquad (3a)$$

Also if this object is surrounded by material having a density, ρ_b, and a mass absorption coefficient, b_b, the roentgen-ray intensity of the emergent beam just outside the object's image is

$$\log G_b = \log G_0 - \int_0^{x_1} b_1\rho_1 dx - \int_0^{x_2} b_2\rho_2 dx \cdots - \int_0^{x_i} b_b\rho_b dx \cdots - \int_0^{x_n} b_n\rho_n dx. \qquad (3b)$$

When equation (3b) is subtracted from equation (3a)*

$$\log G_i - \log G_b = \int_0^{x_i} b_b\rho_b dx - \int_0^{x_i} b_i\rho_i dx. \qquad (4)$$

Under most roentgen conditions, the thickness of an image-producing object is sufficiently small that the values of the mass absorption coefficients remain essentially constant over the integral. Under these circumstances, therefore, equation (4) becomes

$$\log G_i - \log G_b = (b_b\rho_b - b_i\rho_i)x_i. \qquad (4a)$$

Now when roentgen radiation impinges on a roentgenoscopic screen, fluorescent light is emitted and the intensity or brightness of the fluorescence is directly proportional to the intensity of the exposing radiation; that is

$$I = kG \qquad (5)$$

where I is the light emission of the screen

G is the intensity of the roentgen radiation and

k is a constant.

* Since values of b are a function of the spectral distribution of the radiation, the terms which follow $-\int_0^{x_i} b_i\rho_i dx$ in equation (3a) are not exactly equal to those which follow $-\int_0^{x_i} b_b\rho_b dx$ in equation (3b) because the radiation passing through the object will be changed in quality somewhat differently than that transmitted by the surrounding material. This difference however is seldom likely to be large and accordingly in the derivation of equation (4) the two series of terms are considered equal.

Therefore when equations (4a) and (5) are combined,

$$\log I_i - \log I_b = (b_b\rho_b - b_i\rho_i)x_i \qquad (6)$$

where I_i and I_b are the light intensities emitted by the screen in the image and in the surround respectively.

But $\log I_i - \log I_b$ is the contrast exhibited by the image.

Therefore,

$$C_r = (b_b\rho_b - b_i\rho_i)x_i \qquad (6a)$$

where C_r is roentgenoscopic contrast.

If the roentgen radiation is permitted to fall on a roentgenographic film or film-screen combination instead of a roentgenoscopic screen, the density of the processed film will be a function of the quantity of radiation (usually referred to as the exposure) received by the film. This relationship is shown graphically in Figure 6 and may be expressed by the equation

$$D = \int g d \log E + K \qquad (7)$$

where g is the slope of the density vs. log E curve,

E is the quantity of radiation received by the film and

K is a constant.

The value of the factor, g, is governed by inherent characteristics of the film and the conditions under which the film is developed. Through the small ranges of density which usually occur between roentgen images and their surrounding fields, it remains essentially constant and for these conditions equation (7) reduces simply to

$$D = g(\log E - i) \qquad (7a)$$

where i is a constant (see Fig. 6). Now the quantity of radiation received by a photosensitive material is equal to the product of the effective radiation intensity, G, and the exposure time, t; that is

$$E = Gt. \qquad (8)$$

Therefore, equation (7a) may be written

$$D = g(\log G + \log t - i). \qquad (9)$$

When equation (9) is substituted in equation (4a) and terms in G are eliminated

$$D_i - D_b - g(\log t_i - \log t_b) = g(b_b\rho_b - b_i\rho_i)x_i \qquad (10)$$

where D_i and D_b are the densities of the film within the image and the surround respectively and t_i and t_b are the exposure times with which these densities were produced. However, all parts of the film receive the same exposure time. Therefore $t_i = t_b$ and equation (10) reduces to

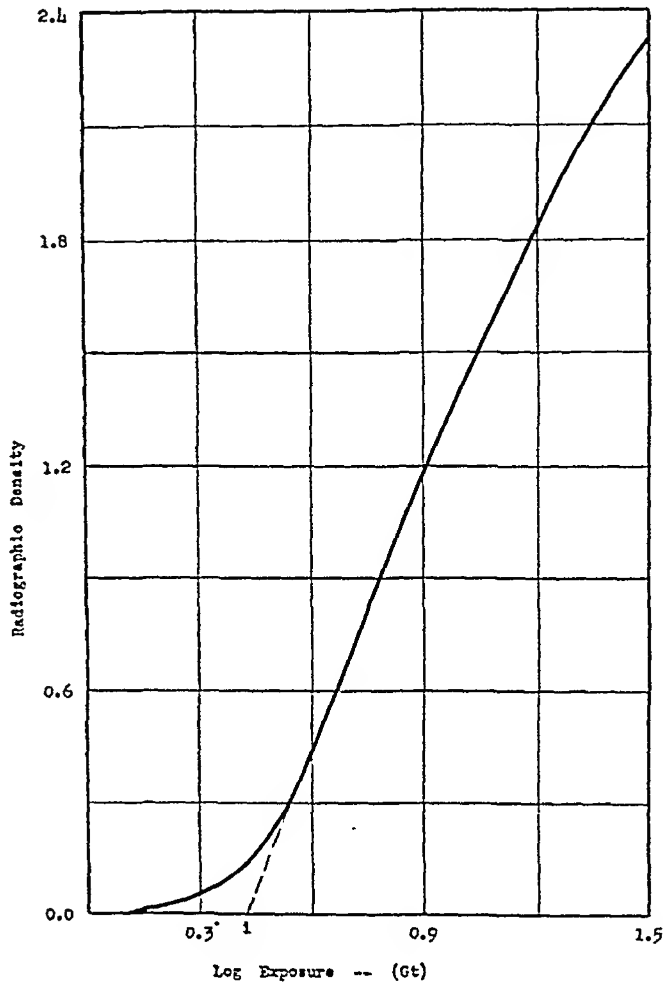

Fig. 6. Relationship between the density (photographic) of a roentgenographic film and the quantity of radiation (exposure) received by the film.

$$D_i - D_b = g(b_b\rho_b - b_i\rho_i)x_i. \qquad (10a)$$

Now $D_i - D_b$ is the roentgenographic contrast exhibited by the image. Accordingly

$$C_f = g(b_b\rho_b - b_i\rho_i)x_i \qquad (10b)$$

where C_f is roentgenographic contrast. It is noteworthy that equation (10b) is also

valid for roentgenoscopic contrast (equation (6a)) if a value of unity is assigned to g.

In the derivation of equation (10b) the influence of scattered radiation arising within the structure under examination was neglected. This phase of the subject however will receive extensive treatment in a later article. For the time being it will suffice to say that when scattered radiation is present equation (10b) should be written

$$C_f = g(b_b\rho_b - b_i\rho_i)\left(\frac{G_{ip}}{G_{ip}+G_{is}}\right)x_i \qquad (11)$$

where G_{ip} is the intensity of the primary roentgen radiation and

G_{is} is the intensity of the scattered radiation within the image boundaries respectively.

Equation (11) specifies contrast as a function of the thickness and density of an image-producing structure and of the intensities of the primary and scattered radiation. Also, through the mass absorption coefficients, b_i and b_b it specifies contrast as a function of the voltage applied to the roentgen tube, of the filtration in the roentgen beam, of the atomic composition of the image-producing structure and of its surrounding material, and of the type of roentgen material on which the radiation impinges (film, film-screen combination or roentgenoscopic screen). The dependence of contrast on roentgen technical factors is clear. In view of the relationship which exists between resolving power and contrast (equations (1a) and (1b)) it is evident that roentgen detail is closely related to roentgen technique.

In addition to contrast, resolving power is a function of the unsharpness with which a roentgen image is recorded. Due to the finite size of the silver halide grains in roentgenographic emulsions and of the fluorescent particles in intensifying and roentgenoscopic screens, the borders of a roentgen image are not perfectly sharp; that is, the transition in density or illumination at the image boundary is not abrupt but instead tends to be gradual. This inherent unsharpness may be accentuated by movement of the structure under examination or by an excessively large target in the roentgen tube. Under certain circumstances such an increase in unsharpness may materially reduce the resolving power of a screen or film and accordingly efforts should be made to reduce target size and anatomical motion to a minimum.

In general, resolving power is an inverse function of unsharpness; that is,

$$R = \frac{m}{U} \qquad (12)$$

where m is a proportionality constant and U is unsharpness. It is evident from equation (12) that if R_e is the resolving power of a material under conditions when extraneous factors producing unsharpness (target size and anatomical movement) are present and R_n is the material's resolving power under conditions in which resolution is limited only by inherent unsharpness,

$$R_e = R_n(U_i/U_o) \qquad (13)$$

where U_i is inherent film or screen unsharpness and

U_o is overall unsharpness (inherent and extraneous unsharpness collectively).

That is, extraneous unsharpness reduces resolving power by a factor U_i/U_o.

From the foregoing it is clear that equations (1a) and (1b) to be more generally applicable should be written

$$R = R_n(1 - e^{-aC})(U_i/U_o) \qquad (14a)$$

and

$$R = R_n aC(U_i/U_o) \qquad (14b)$$

where

$$C = g(b_b\rho_b - b_i\rho_i)\left(\frac{G_{ip}}{G_{ip}+G_{is}}\right)x_i$$

Equations (14a) and (14b) are of fundamental importance for they establish a direct quantitative relationship between roentgen detail and the many factors upon which roentgen detail is dependent. If sufficient data be available, they permit an unequivocal comparison of the merits of

various roentgen procedures such as photofluorography versus general roentgenography, low kilovoltage technique versus high kilovoltage technique and small target size versus large target size. In forthcoming publications of this series, quantitative data on each of the factors appearing in these equations will be given. In Part II methods for measuring the maximum resolving power, R_m, and the resolution coefficient, a, of roentgen materials will be described. Data on a variety of films and screens will be included in this report.

REFERENCES

1. Mees, C. E. K. The Theory of the Photographic Process. The Macmillan Co., New York, 1942.
2. White, D. R. Personal communication.
3. Frieser, H. Die photographische Auflösung von Strichrastern in Abhängigkeit von der Beschaffenheit der Raster. *Ztschr. f. wissensch. Photograph., Photophys. u. Photochem.*, 1938, *37*, 261.

EBSTEIN TYPE OF TRICUSPID INSUFFICIENCY*

ROENTGEN STUDIES IN A CASE WITH SUDDEN DEATH AT THE AGE OF TWENTY-SEVEN

By DONALD deF. BAUER, M.D.
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TRICUSPID insufficiency is infrequently diagnosed clinically. A study at New Orleans indicated that only 1 case in 30 is recognized.[12] Congenital tricuspid insufficiency of the Ebstein type has been reported only 16 times and has apparently never been diagnosed before postmortem examination. In most cases of tricuspid insufficiency the expectancy of life is considerably shortened. The average age at death in Ebstein's disease is twenty-five years. Two individuals lived to be sixty; 4 others lived beyond the age of thirty. The causes of death are shown in Table I. The incidence of sudden death seems to be rather high, but the series is too small for conclusions to be drawn. Nevertheless it is interesting to consider a fourth case with sudden death, followed over a period of nine years, the seventeenth case to be reported.

CASE REPORT

The patient was first seen when she was eighteen years old. She complained of weakness, easy fatigability and breathlessness in response to minor exertion. The most distressing symptom was "heart flutter." She was one of three children. No history of heart disease in her family could be elicited. From the age of six this girl had suffered palpitation and shortness of breath on exertion. No precordial pain, cough, sputum, edema or cyanosis had bothered her. Menses began at thirteen and were always regular. Intermittent attacks of severe palpitation, lasting many hours, had recently begun, with onset following excitement. Quinidine therapy afforded relief for these attacks of paroxysmal tachycardia.

TABLE I

CAUSE OF DEATH IN REPORTED CASES

Date	Author		Sex	Age	Cause of Death
1866	Ebstein		M	19	Tuberculosis and congestive failure
1886	Marxsen		F	61	Ulcerative colitis
1900	MacCallum		M	30	Pulmonary tuberculosis
1903	Schönenberger		F	4.5	Sudden death
1903	Geipel	Case I	M	18	Not stated
		Case II	?	15	Not stated
		Case III	M	15	Cerebral embolus
1908	Malan		M	60	Mesenteric thrombosis
1913	Heigel	Case I	F	10	Meningitis
		Case II	F	3	Bronchopneumonia
		Case III	F	38	Cord paralysis
1919	Blackhall-Morison and Shaw		M	38	Tuberculosis; meningitis
1922	Blackhall-Morison		M	33	Sudden death (no previous ill health)
1927	Arnstein		F	20	Tuberculosis
1928	Abbott		M	16	Erysipelas
1938	Yater and Shapiro		F	21	Sudden death
1944	Bauer		F	27	Sudden death

Statistics: 8 M, 8 F, 1 unknown; average age, 25.2 years.

* From the Department of Radiology and the Department of Pathology of Duke University School of Medicine and Duke Hospital, Durham, North Carolina.

The patient weighed 55.5 kg. and was 166 cm. tall. She was not jaundiced nor cyanotic. There was no clubbing and the neck veins were not distended. A marked precordial heave was evident; but a true seesaw movement of the chest wall was not present (absence of outthrust over the liver). A systolic thrill was palpable over the apex. In the same area could be heard systolic and mid-diastolic murmurs. The murmur of systole was audible over the entire precordium but it was maximal in the fourth left interspace at the sternal border. The lungs were clear. The liver could not be felt. The pulse rate was 75. The electrocardiogram showed normal sinus rhythm and bundle branch block.

Roentgenoscopy and roentgenography of the chest showed marked enlargement of the heart in all diameters. Pulsations were rapid and strong. The aorta did not appear dilated. The right cardiac margin, composed probably of the right atrium, projected to the right and posteriorly. Measurements were: midline to the right border, 7.5 cm.; midline to the left border, 11 cm.; great vessels, 4.6 cm.; transverse diameter of the chest, 24 cm.

The patient was not admitted to the hospital, but was seen several times in the outpatient clinic, up to the time of an attack of "rheumatism" at the age of twenty. Thorough examination at that time disclosed that her "rheumatism" was an acute gonococcal arthritis involving the right wrist. Since the previous study, she had lost 4 kg. and was 7 kg. below ideal weight for her height and age. Bouts of palpitation and dyspnea on exertion were less troublesome because she had learned to accept her physical limitation and was leading a less active life. There was no clubbing, jaundice, dyspnea, distention of neck veins or pulmonary congestion. One experienced observer noted slight cyanosis (but this may have been related to chemotherapy).

Teleroentgenograms and roentgenoscopy showed increase of the transverse diameter of the heart since the previous examination (two years before). Measurements now were: midline to the right border, 8 cm.; midline to the left border, 11.5 cm.; great vessels, 4.3 cm.; transverse diameter of the chest, 25 cm. The enlargement seemed to be largely confined to the right side of the heart. The electrocardiogram showed normal sinus rhythm at a rate of 88. Right bundle branch block was noted. The impression of most observers was that the patient had some form of complicated congenital cardiac malformation, possibly tetralogy of Fallot.

At the age of twenty-seven the patient was admitted again, for study of her cardiac status and consideration of the advisability of oophorocystectomy. For the past five years she had noticed a slowly growing abdominal mass which the gynecologists believed to be a benign ovarian cyst. The patient complained of dyspnea on climbing stairs (even very slowly) and she limited her activities carefully to prevent unpleasant manifestations of her cardiac insufficiency. Attacks of paroxysmal tachycardia were very infrequent; minor episodes of palpitation were always related to physical exertion, worry or excitement. She weighed 60.6 kg., a gain of 9.3 kg. since the last admission. Consequently she was up to the average weight for her height and age. There was no cyanosis, clubbing, jaundice, distention of neck veins, orthopnea or pulmonary congestion. The apical systolic thrill was present as before. At the apex and in the third, fourth and fifth left interspaces parasternally there was a loud, low-pitched, rough systolic murmur synchronous with the thrill. An early diastolic murmur was heard only in the fourth and fifth left interspaces parasternally. The liver was not palpable. The blood pressure was 105 systolic and 80 diastolic.

The electrocardiogram showed the same general picture as previously, with normal sinus rhythm and right bundle branch block. The heart rate was 77. Roentgenogram of the chest demonstrated rapid, feeble pulsations and marked enlargement of the right atrium and ventricle. The heart measurements were: midline to the right border, 9 cm.; midline to the left border, 12 cm.; great vessels, 5 cm.; transverse diameter of the chest, 25 cm. The kymogram showed rapid, irregular pulsations, suggesting fibrillation or myocardial degeneration. The heart was larger in all diameters than at the examinations nine and seven years previously and the increase was chiefly right sided.

Oophorocystectomy was performed under spinal anesthesia. A papillary cystadenoma of the ovary was removed. The postoperative course was entirely satisfactory and the patient was discharged on the twelfth postoperative day. She returned for dressings on the twenty-first and twenty-eight postoperative days. She

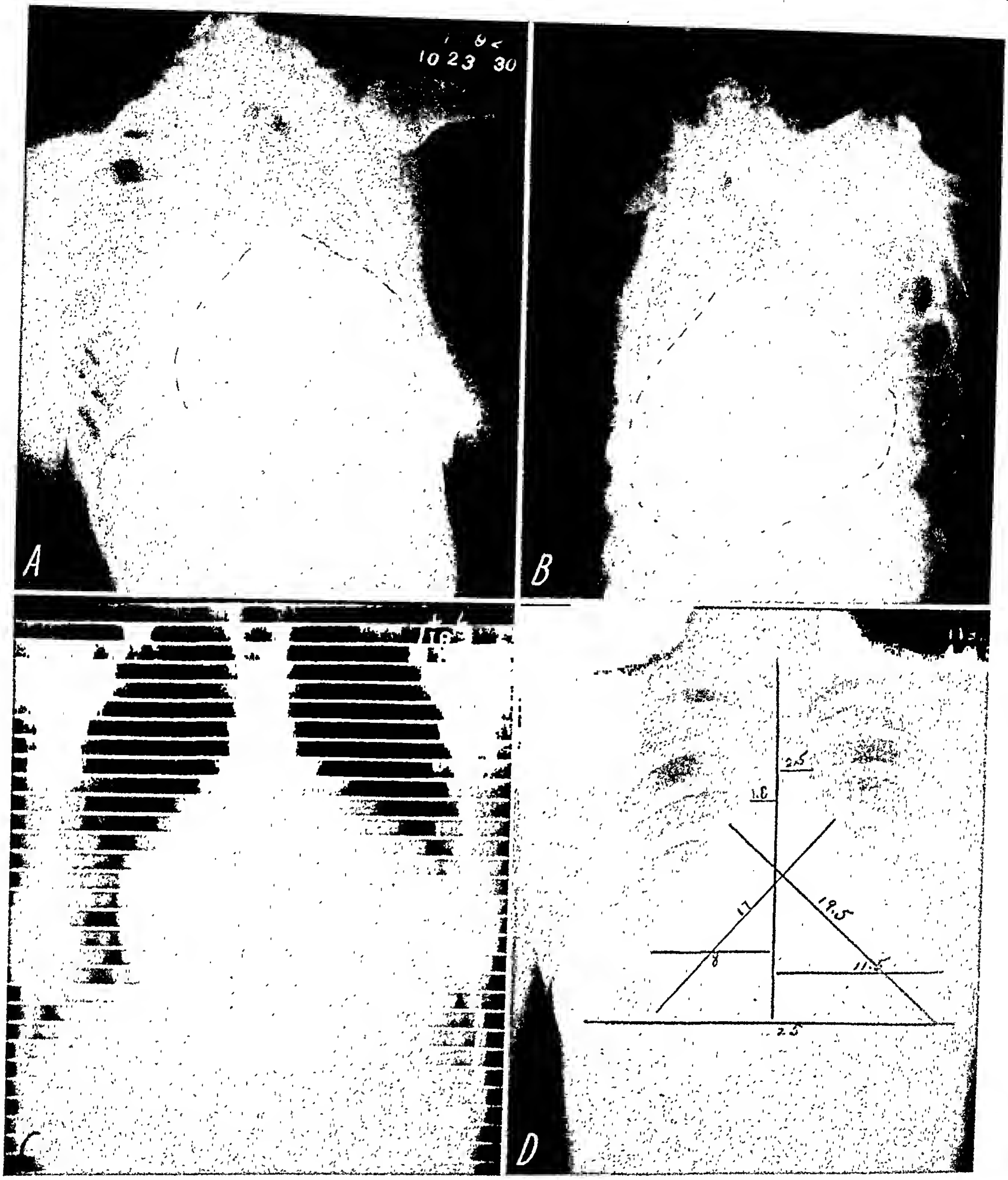

Fig. 1. *A*, right anterior oblique view at the age of eighteen, showing enlargement of the right atrium. *B*, left anterior oblique view at the age of twenty, showing the huge right heart without esophageal displacement. *C*, kymogram at the age of twenty-seven, showing feeble pulsations and irregularity. *D*, posteroanterior view at the age of twenty, with cardiac measurements.

died suddenly during the latter clinic visit. While arranging her clothes after climbing down from the examining table, she cried out for help. She was found leaning against the examining table and she was cyanotic with cool, moist skin. Her color improved when she had been lifted back to a supine position on the table; but she tossed from side to side and conversed in garbled, incoherent speech. Tachypnea was evident, but not orthopnea. Oxygen and carbon dioxide were administered but respirations ceased. Artificial respirations and intracardiac

coramine were without avail. The attending physicians believed death was caused by pulmonary embolism.

Autopsy. The right hand and forearm (involved seven years ago in gonococcal arthritis) are atrophic. The peritoneal cavity contains about 200 cc. of clear liquid. Each pleural cavity contains about 50 cc. of clear liquid. The pericardial sac is fluctuant and distended with 500 cc. of blood-colored, unclotted liquid. Pericardial surfaces are not smooth but have many minute, wart-like excrescences and some short, fibrous strands. No evidence of myocardial perforation, coronary rupture or pulmonary emboli is found. The heart weight, 470 gm., is approximately 200 gm. more than the average for a woman of this age. It is a huge heart with striking predominance of right-sided enlargement. The left atrium measures 5 by 5 cm. There is no atrial rheumatic patch. The foramen ovale is patent to the probe. The mitral valve is 7 cm. in circumference. Its free margin is definitely thickened, and some of the chordae tendineae are thickened but not shortened. The valve appears competent and not stenosed. The left ventricle measures 9 by 4 cm. Its wall is about 12 mm. in thickness. There is no ventricular septal defect. The aortic valve circumference is 5.5 cm. This valve is not thickened, but is well formed, smooth and delicate. The aorta beyond is neither stenosed nor dilated. The ligamentum arteriosum has replaced the ductus arteriosus.

The right atrium measures 5.5 by 8 cm. and is obviously dilated and hypertrophied. The coronary sinus is greatly dilated. The right atrioventricular orifice measures 21 cm. in circumference. This, however, is not the line of attachment of the insufficient tricuspid valve. The total circumference of the line of attachment is 30 cm. The anterior cusp is properly attached at the atrioventricular sulcus. The left or septal half of the posterior cusp is attached to the sulcus, but the remainder of the posterior cusp is attached to the ventricular wall in a curved line which sweeps progressively downward to the posteroseptal commissure. The septal cusp, beginning at the anteroseptal commissure, likewise attaches to the ventricular wall in a downward sweep with a maximum departure of 8 cm. from the atrioventricular sulcus. The papillary muscles, almost insignificantly small structures, are hardly distinguishable from columnae carneae. This is particularly true because the chordae tendineae are extremely short, thus effectively binding the valve leaflets to the ventricular walls and making the valve totally insufficient. The moderator band is clearly discernible. The right ventricle measures 12 by 12 cm. The normal appearing pulmonary valve measures 6.5 cm. in circumference. The artery beyond is neither stenosed nor dilated, but is uniformly, slightly smaller in caliber than usual.

Microscopic examination of the pericardial excrescences shows a chronic type of pericarditis with fibrous thickening, numerous lymphocytes and many iron-holding macrophages. The myocardium is not scarred; no Aschoff bodies are found. The thickened portions of the mitral valve show a few round cells but no vascularization or definitive changes. All the viscera show evidence of acute congestion. There is no central necrosis in the liver, but there is some periportal fibrosis with moderate round cell infiltration.

Postmortem Roentgen Studies. Additional roentgenograms were taken of the heart specimen in an attempt to obtain further information of value for the interpretation of the antemortem teleroentgenograms. Factors used were: 72 inches, 20 ma., 35 kv., and $2\frac{1}{2}$ seconds. By means of diaphragms sewn into the specimen at the true atrioventricular orifice and at the actual line of attachment of the tricuspid valve, it was possible to visualize separate portions of the right side of the heart with barium. The illustrations include anteroposterior and right-left views of the heart under these conditions.

The barium-filled right atrium is shown in Figure 2. Evidently the upper border of the right auricular appendage formed most of the right border of the cardiac shadow in the teleroentgenograms. The comparative size of the right and left sides of the heart may be judged from Figure 3 where the entire right (functionally single chambered) side is barium filled while the left side is free of barium. In the same roentgenograms can be seen the obvious dilatation of the superior vena cava, which caused widening of the shadow of the great vessels in the teleroentgenograms. The left border of the heart was formed by the right ventricle; the left ventricle is entirely hidden (behind) by the barium in the right ventricle.

Some idea of the degree of displacement of the attachment of the tricuspid valve may be obtained from the roentgenograms in Figure 3.

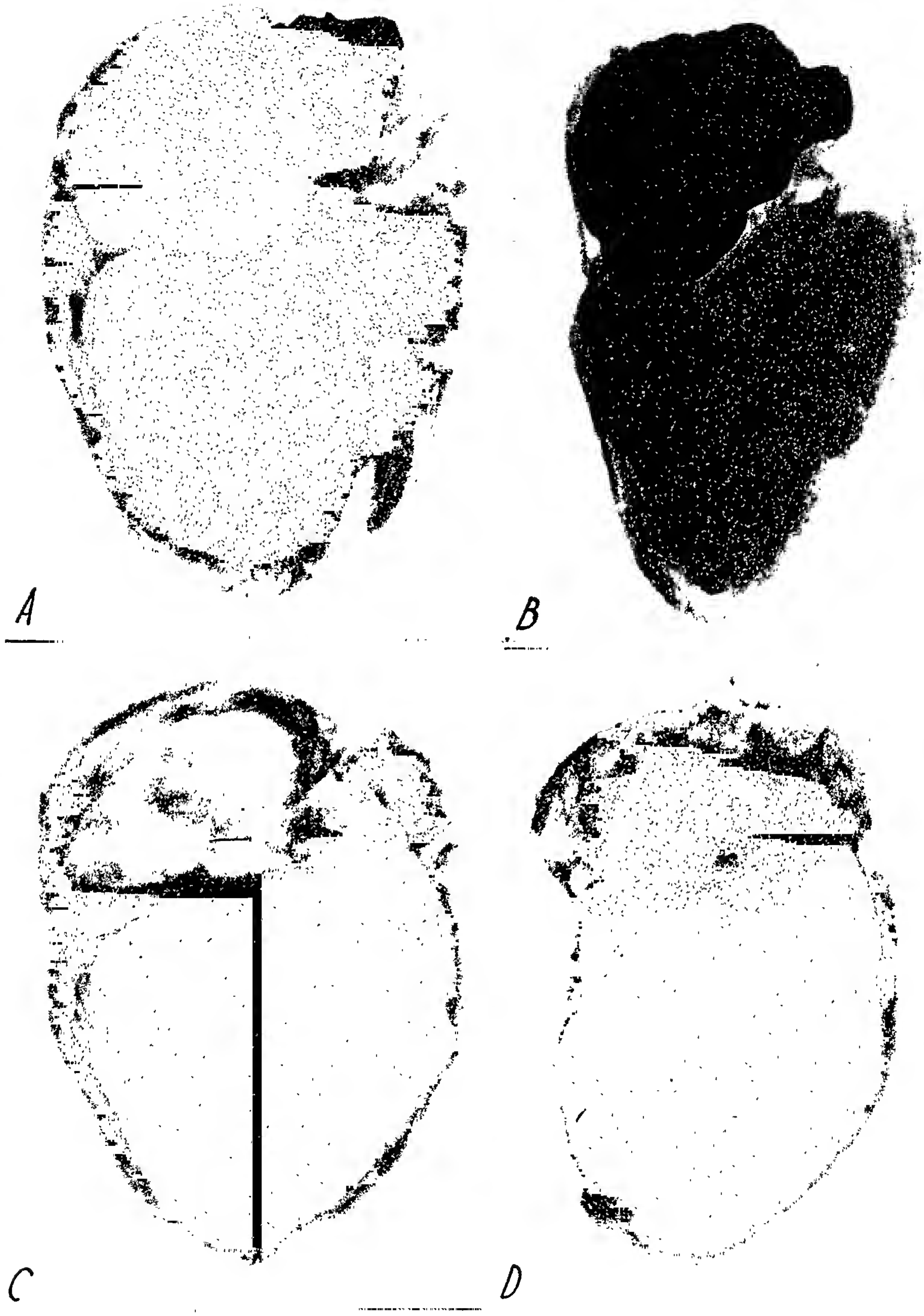

FIG. 2. *A*, posteroanterior view of heart specimen with barium in the right atrium to show that the right border of the heart in Figure 1*D* was formed by the right atrium. Compare with Figure 4*A*. *B*, right lateral view with barium in the right atrium. *C*, posteroanterior view with barium in the entire right ventricle. Compare with Figures 1*D* and 4*A*. *D*, right lateral view of the same specimen.

Fig. 3. *A*, posteroanterior view of the heart specimen with barium in the portion of the right ventricle (the "atrialized" portion) between the two dotted lines of Figure 4*C*. *B*, right lateral view of the same specimen. *C*, anteroposterior view with barium filling the entire right side of the heart, showing that almost none of the left side could be seen roentgenoscopically in the posteroanterior position. *D*, right lateral view of the same specimen.

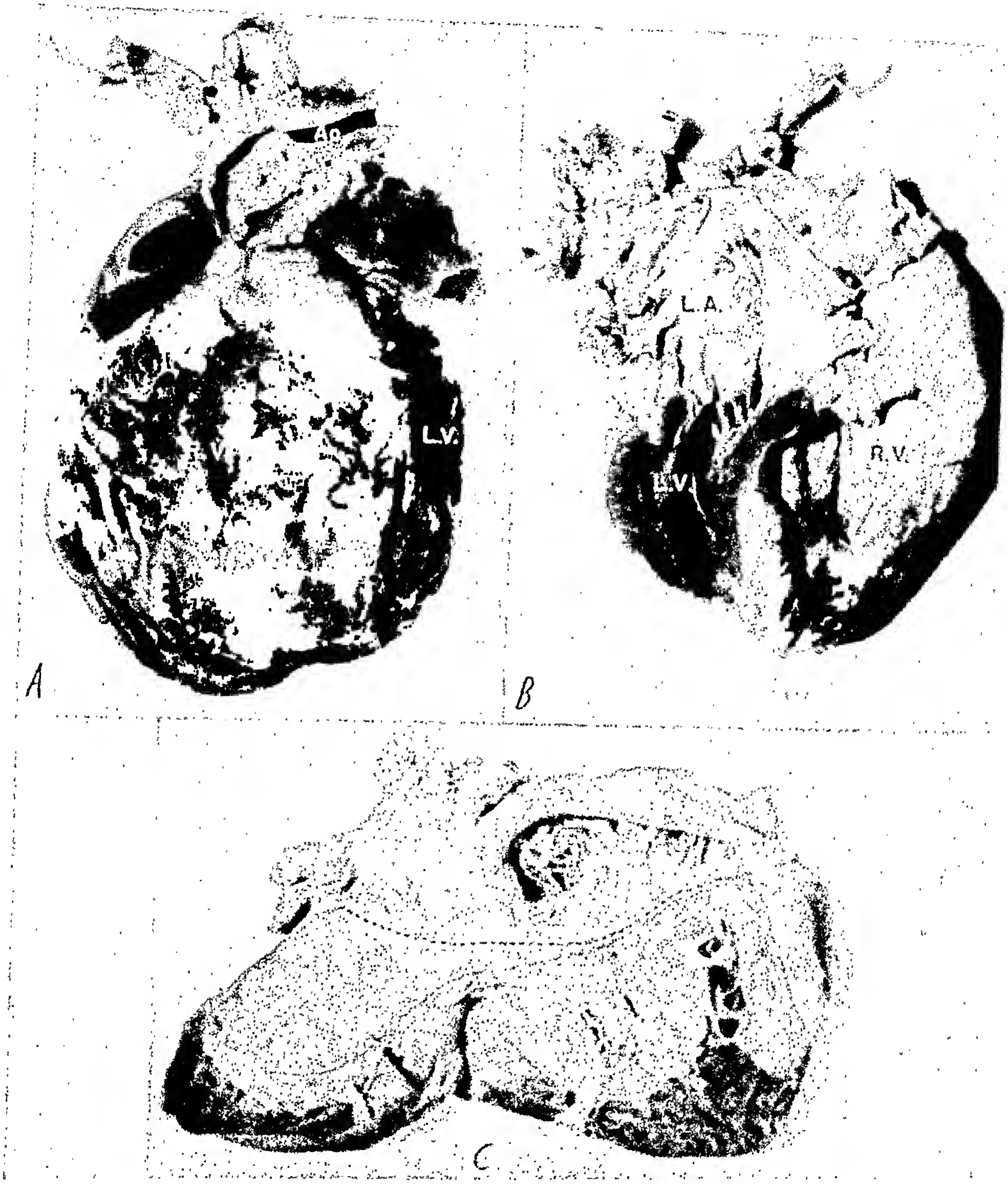

FIG. 4. *A*, anterior view of the heart specimen rotated slightly to the right to bring the left ventricle (*L.V.*) into view. The pulmonary artery, seen filled with barium in Figure 2*C*, is just below the aorta (*Ao.*). The photograph shows the pericardial roughening. *B*, the relatively small left ventricle (*L.V.*) is shown in this view of the posterior aspect of the heart. The left atrium (*L.A.*) is above. *C*, the right side of the heart opened to show the congenital defect. The black line marks the atrioventricular sulcus, the normal line of attachment for the tricuspid valve. The white line marks the actual attachment of the tricuspid valve.

The barium-filled portion here shown is that part of the right ventricle between the atrioventricular sulcus (the line of attachment of the normal tricuspid) and the actual line of attachment of the valve (Fig. 4*C*). From the anteroposterior and lateral views it is clear that a large portion of the right ventricle has been "atrialized" by the displacement.

DISCUSSION

The gross findings are those of Ebstein's disease. "Ebstein's disease of the heart is a rare congenital malformation consisting essentially of downward displacement of the tricuspid valve in an otherwise completely developed heart. The right auricle is greatly enlarged, and the foramen ovale is usually patent. The true right auriculoventricular ostium is enlarged."[13]

The clinical findings outlined above are entirely compatible with the autopsy findings. The absence of venous pulsations in the jugular veins and the liver is not uncommon in tricuspid insufficiency when the right atrium has become greatly dilated. Cirrhotic changes in the liver, in longstanding tricuspid insufficiency, tend also to make imperceptible the pulsations of this organ. Visible pulsations of the hypertrophied and dilated right chambers were noted in the right hemithorax. Intermittent pericardial effusion was produced by the increased pressure on the coronary sinus. At the time of death there was also effusion into the pleural and pericardial cavities and acute congestion of all the viscera as a result of acute circulatory failure.

Yater and Shapiro[13] reported bundle branch block in their case. Their careful histopathologic studies failed to reveal an explanation. Their report carries no mention of pericardial effusion, but there was acute congestion of the viscera. Various degrees of heart block have been found associated with pericardial effusion, and this may be the explanation. Fibrillation, which also may be produced by effusion, was inferred from the kymogram in the present case during the patient's last hospital admission. Fibrillation may also be produced by increased pressure in the right atrium.[12] The thrill and murmurs heard are compatible with those of tricuspid insufficiency.

The immediate cause of death was acute circulatory failure. Tamponade did not initiate the difficulty. It is probable that a small amount of clear fluid was present in the pericardial sac prior to the acute episode preceding death. The addition of blood was apparently caused by the heroic treatment with intracardiac coramine, after cyanosis and coma had supervened. The evidence of chronic pericarditis may be interpreted as support for the belief that increased pressure on the coronary sinus caused intermittent pericardial effusion.

The roentgenologic evidences of tricuspid insufficiency in this case were: massive enlargement of the cardiac shadow to the right and left in the absence of pulmonary congestion and in the presence of vigorous pulsations; prominent upper mediastinal shadow with widened superior vena cava; enlargement of the right atrium and ventricle and actual difficulty in visualization of the small left ventricle.

At the time of her admission for surgical attention, the patient was a poorer risk than at any time when she had previously been seen. This statement is not intended as criticism of the treatment the patient received, because it is not evident that the operative procedure contributed in any way to her death. The comparison of findings at the time of the patient's second ad-

Table II

COMPARISON OF FINDINGS IN THREE EXAMINATIONS

Age yr.	Lungs	Pulsations	Rhythm	Median Right cm.	Median Left cm.	Vessels	QRS
18	Clear	Strong	Regular	7.5	11.0	4.6	0.15
20	Clear	No mention	Regular	8.0	11.5	4.3	0.15
27	Clear	Feeble	Fibrillation (?)	9.0	12.0	5.0	0.16

mission, with previous findings, provides information that should be of value in considering the prognosis of an individual with tricuspid insufficiency. Except for a slight increase in the QRS interval there was no essential change in the electrocardiogram. Physical findings had not altered. The roentgen changes were definite, however. These are set forth in Table II. There is no real mystery in the death of this patient or the patients in the other 3 cases in which sudden death has been reported. Apparently each of these individuals had exhausted the cardiac reserve so that even a minor increase in routine activities was sufficient to institute irreversible changes leading swiftly to death.

SUMMARY

A seventeenth case of congenital tricuspid insufficiency of the Ebstein type is reported. It is the fourth case with sudden death. The patient was a female, aged twenty-seven, who was studied on three occasions over a period of nine years. Postmortem roentgen studies of the heart are compared with teleroentgenograms made during life to demonstrate the changed relation of the heart chambers. Some roentgenographic observations, which may be helpful in problems of prognosis in patients known to have tricuspid insufficiency, are set forth.

REFERENCES

1. Abbott, M. E. In: Bedside Diagnosis. George Blumer, Editor. W. B. Saunders Co., Philadelphia, 1928, *2*, 482–485.
2. Arnstein, A. Eine seltene Missbildung der Trikuspidalklappe ("Ebsteinsche Krankheit"). *Virchow's Arch. f. path. Anat.*, 1927, *266*, 247–254.
3. Blackhall-Morison, A., and Shaw, E. H. Cardiac and genito-urinary anomalies in the same subject. *J. Anat.*, 1919–1920, *54*, 163–165.
4. Blackhall-Morison, A. Malformed heart with redundant and displaced tricuspid segments and abnormal local attenuation of the right ventricular wall. *J. Anat.*, 1922–1923, *57*, 262–266.
5. Ebstein, W. Ueber einen sehr seltenen Fall von Insufficienz der Valvula tricuspidalis, bedingt durch eine angeborene hochgradige Missbildung derselben. *Arch. f. Anat., Physiol. u. wissensch. Med.*, 1866, pp. 238–254.
6. Geipel, P. Missbildungen der Tricuspidalis. *Virchow's Arch. f. path. Anat.*, 1903, *171*, 298–334.
7. Heigel, A. Ueber eine besondere Form von Entwicklungsstörung der Trikuspidalklappe. *Virchow's Arch. f. path. Anat.*, 1913, *214*, 301–319.
8. MacCallum, W. G. Congenital malformations of heart as illustrated by the specimens in the pathological museum of the Johns Hopkins Hospital. *Johns Hopkins Hosp. Bull.*, 1900, *11*, 69–71.
9. Malan, G. Ueber die Entstehung eines Herzgeräusches. *Centralbl. f. allg. Path. u. path. Anat.*, 1908, *19*, 452–455.
10. Marxsen, T. Ein seltener Fall von Anomalie der Tricuspidalis. Kiel Thesis, 1886.
11. Schönenberger, F. Ueber einen Fall von hochgradiger Missbildung der Tricuspidalklapper mit Insufficienz derselben. Zurich Thesis, 1903.
12. Winsor, T., and Burch, G. E. Study of incidence of tricuspid regurgitation at a large general hospital in the South. *South. M. J.*, 1942, *35*, 1065–1069.
13. Yater, W. M., and Shapiro, M. J. Congenital displacement of tricuspid valve (Ebstein's disease); review and report of a case with electrocardiographic abnormalities and detailed histologic study of conduction system. *Ann. Int. Med.*, 1937–1938, *11*, 1043–1062.

Vol. 54, No. 2

THE ROENTGENOLOGICAL MANIFESTATIONS OF AMEBIASIS OF THE LARGE INTESTINE*

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AMEBIASIS has a wide geographical distribution. In the Middle East the disease occurs endemically. In the presence of stenosis of the large intestine, roentgenologists should therefore always consider the differential diagnosis between cancer and amebiasis. At present, when members of the Army serving overseas may bring the disease home on their return, it seems necessary to draw attention to the roentgenological manifestations of amebiasis of the large intestine.

Two types of amebiasis of the colon are to be distinguished: (1) the diffuse type and (2) the localized type.

(1) *The Diffuse Type.* The lesions are scattered all over the colon, the roentgenological aspect being similar to that seen in cases of idiopathic or ulcerative colitis.

In 186 autopsies on persons dying of dysentery, Clark found 60 per cent which presented the diffuse type while in 40 per cent pathological changes of a local nature were established.

The two varieties, the diffuse and the localized, may co-exist. This means that the colon which may be affected throughout almost its whole length may, in addition, show one or several stenosed areas.

(2) *The Localized Type.* This type gives a more characteristic roentgen appearance. The individual portions of the colon are involved in the following order of frequency: cecum, ascending colon up to the hepatic flexure, sigmoid, rectum. It appears that the opaque enema is more reliable and should be preferred to the barium meal.

"Amebic granuloma" in conjunction with excessive scarring (spasms, edema and pericolic inflammatory tissue) may lead to partial obstruction of the lumen, creating the impression that one is dealing with cancer of the colon, and operations have even been performed because of this misleading appearance.

Before embarking upon a detailed analysis of the roentgen manifestations of amebiasis, it should be emphasized that close cooperation between clinic, laboratory and roentgen department is indispensable in order to establish the definite diagnosis of an amebic filling defect. The roentgenological distinction between stenosis due to amebic granuloma and that due to malignant new growth is based on the following points:

(1) In amebiasis the colic and pericolic inflammatory process usually occupies an extensive segment of the colon, while cancer is practically confined to a relatively short portion of the large intestine (Fig. 1).

Fig. 1. There is an area of constriction about 20 cm. long between sigmoid and descending colon. Haustration and mucosal relief are practically intact.

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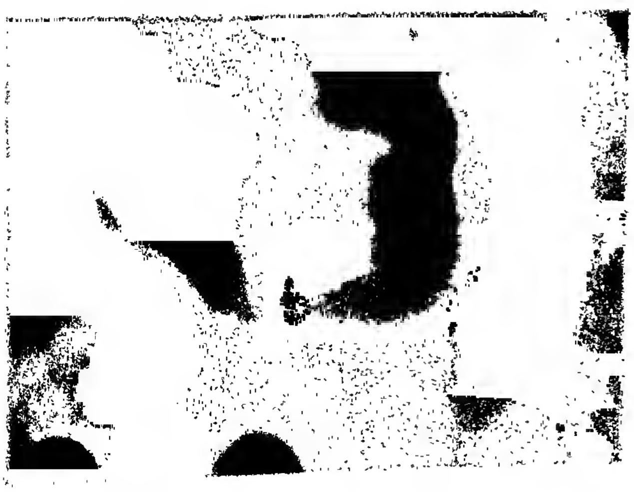

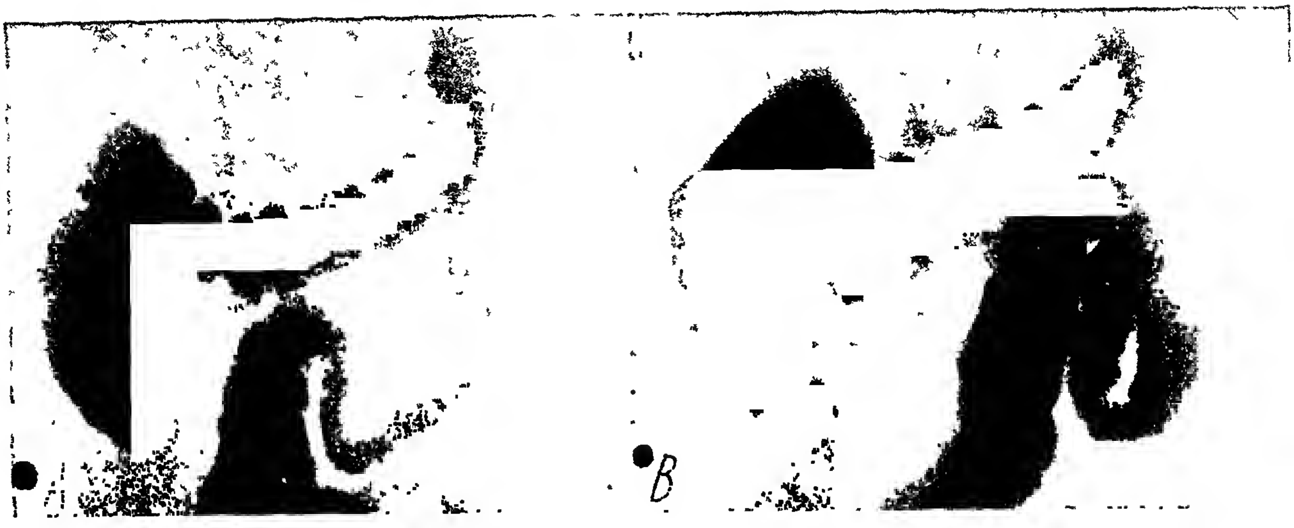

Fig. 5. A, constricted portion of colon about 12 cm. long, with gradual transition from the normal to the affected part. Haustration and mucosal relief are practically intact. (The transition is so gradual that it is impossible to draw a definite line between the normal and pathological area.) *B*, upon additional filling with barium the lumen of the constricted portion has become wider.

(7) In amebiasis the mucosal relief of the involved portions is more or less regular while in cancer it is irregular (Fig. 1, 2, 3, 4 and 5*A*).

(8) After vigorous anti-amebic treatment, follow-up examinations show a more or less complete restoration to normal. In a number of cases the site of stenosis can no longer be identified, while in others the lumen has become enlarged, the response depending on the type of case, whether stenosis was due to edema, proliferation of tissue or fibrous transformation of the granulation tissue (Fig. 6, *A* and *B*).

While in the presence of obstruction due to malignant new-growth early operation is essential, the least supicion that stenosis may be due to amebae is an absolute contraindication to operation. It should be borne in mind that laparotomy in case of latent amebic infection may endanger the patient's life and be a potential cause of death.

We saw a patient on whom gastrectomy had been performed for duodenal ulcer and in whom a latent amebic infection flared up following operation. The patient died after a short period of fever. Autopsy revealed an amebic abscess of the liver in the neighborhood of the site of operation. We also saw a case of death after colostomy performed for the relief of amebic stenosis although usually the operative mortality for this operation is negligible.

Fig. 6. *A*, narrowed area about 6 cm. long with normal mucosal relief in the middle of the transverse colon. *B*, complete disappearance of stenosis after anti-amebic treatment.

Mention should be made of the fact that amebic granulation tissue may be radiosensitive. In a case of extensive stenosis of the transverse colon laparotomy revealed an inoperable cancer. The patient was therefore given roentgen therapy following which the tumor disappeared and the normal lumen was restored (Fig. 7, *A* and *B*).

(*e*) the frequently gradual merging of the filling defect into the normal contours of the intestine;

(*f*) the partial maintenance of elasticity of the intestinal wall in amebiasis evidenced by widening of the lumen upon introduction of barium;

Fig. 7. *A*, very long (about 25 cm.) stenosed segment of the transverse colon. *B*, complete restoration of normal conditions after roentgen treatment.

COMMENT AND SUMMARY

Roentgen examination is very helpful in the establishment of the diagnosis of amebiasis of the colon. Roentgenologists should therefore be familiar with this condition and its roentgenological manifestations.

(1) *The Diffuse Type.* The roentgenological appearance is not characteristic and resembles that of idiopathic or ulcerative colitis.

(2) *The localized type* is characterized by

(*a*) the relative length of the stretch occupied by the filling defect of the colon;

(*b*) the often multiple occurrence of obstruction of the lumen;

(*c*) the incompleteness of the narrowing of the lumen as compared to malignant stenosis;

(*d*) the insignificance or even absence of pain upon distention by the barium enema in contrast to the acute pain of malignant stenosis;

(*g*) the more or less normal mucosal relief in the involved portion, and

(*h*) the more or less complete restoration to normal after vigorous antiamebic treatment.

REFERENCES

1. Bell, J. C. Roentgenologic studies of the large bowel in infection with *Endamoeba histolytica* before, during and after treatment. Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 916–924.
2. Christopher, F. Stenosis of the large bowel due to amebiasis. *Surgery*, 1938, *3*, 75–77.
3. Clark, H. C. Distribution and complications of amebic lesions found in 186 postmortem examinations. *Am. J. Trop. Med.*, 1925, *5*, 157–171.
4. Reed, A. C., and Anderson, H. H. Amebiasis and cancer of colon. *Am. J. M. Sc.*, 1936, *191*, 237–250.
5. Vallarino, J. J. Preliminary report on value of roentgen ray in estimating extent of amebic infection of large intestine. *Am. J. Trop. Med.*, 1925, *5*, 149–156.
6. Weber, H. M. Non-neoplastic tumefactive lesions of large intestine; inflammatory tumefactions. Am. J. Roentgenol. & Rad. Therapy, 1936, *36*, 637–647.

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THE SIGNIFICANCE OF CANNON'S POINT IN THE NORMAL AND ABNORMAL FUNCTIONS OF THE COLON*

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If we observe the form and filling of the normal colon twenty-four hours after a barium meal, we find an accidental form of haustration whereby the forces of kneading and propulsion have left their imprint on the drying barium. There are zones of continued filling and areas of intermissions, small balls and large sausage shaped rolled forms; and it is difficult, if not impossible, to analyze the forces which result in such an appearance.

Occasionally, however, we see a roentgenogram, taken twenty-four hours after a barium meal or even immediately after a barium enema has been expelled, where the retained barium gives a clear view of the divisions involved and of the impulses working along the colon, just as cloud formations are indefinite and variable but tell the meteorologist the forces of wind and weather.

We may note that the first part of the transverse and ascending colon up to a certain point is contracted, while the second part and the descending colon are of normal diameter (Fig. 2). In another group of cases the reverse process is evident (Fig. 1): the ascending colon and the first part of the transverse colon are wide, the second part of the transverse colon and the descending colon are contracted. Not once or twice did we note such findings, but very frequently, after we were aware of the phenomenon. At times, however, we found instead of such a division only a contraction ring at a certain point (Fig. 3).

This point where such change of diameter and function occurs can be easily established and we found it quite frequently at the right side of the spine between the first and second third of the transverse colon; never much farther distal than the middle third, never as far proximal as the right flexure. Such repeated observation con-

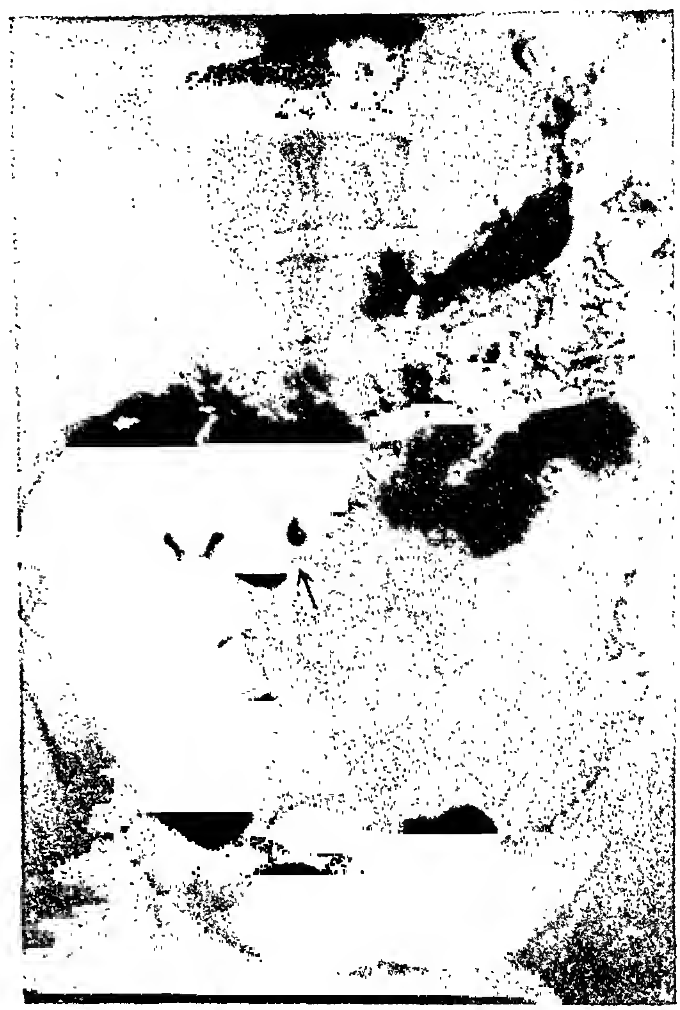

Fig. 1. Demarcation of Cannon's point (arrow). Ascending and transverse colon wide up to Cannon's point, transverse and descending colon contracted beginning at this point.

vinces me that the point is of great functional significance.

In preparation for animal experiments, I found the surprising fact that such animals as rabbits and cats not only occasionally show such a division of the colon, but that the division is regularly established is well

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Fig. 2. The reverse process: contraction of the first neurological unit, normal wide second neurological unit. Cannon's point clearly marked.

known to experimental physiologists, and was demonstrated by Garry in a form which shows close analogy to the colon in man (Fig. 4).

The earliest observations concerning this phenomenon were made by Cannon who, experimenting on animals, found and described in 1902 a ring of contraction in the large bowel of the cat, which divides the colon into two partitions. His findings were confirmed by Boehm about thirty years ago who, first in rabbits and later in man, found the same contraction in the transverse colon and observed different functions on both sides of it: tonic contraction and antiperistalsis in the proximal part, deep segmentation and ball formation in the distal part of the colon. Case, in his study of colon motility, peristalsis, and antiperistalsis, observed the phenomenon of the contraction ring in man usually to the right of the midline in the transverse colon, confirming the earlier work of Cannon and adding many new observations which he presented at the Seventeenth International Congress of Medicine in London in 1913. He showed that the prevailing movement in the proximal colon is antiperistalsis, the movement of waves backward towards the cecum, while the distal colon has as its characteristic motility an onward movement.

These important findings seemed to be neglected during the following years, probably because it was felt they were of no clinical significance. Only once in discussing several other "sphincters" along the colon does Balli mention that area as another sphincter location. It is my opinion that most of these sphincters, with the possible exception of the ileocolic, are reflexes and do not have the anatomical structure of a sphincter.

I suggested that this significant point be called Cannon-Boehm's point in honor of

Fig. 3. The ring-like form of spastic contraction at Cannon's point. For explanation see text.

the early observers and it is referred to as such in recent literature. In one fact of great significance I am departing, however, completely from the explanation given by Cannon, Boehm, and Balli. Cannon observed here a contraction ring; Boehm functional divisions between the first and second part of the colon of the cat; Buzzi and Balli described it vaguely as a sphincter. No hypertrophy of muscle fibers or no accumulation of ganglion cells suggestive of a sphincter has ever been found in that area. Our own examinations over a long period of time have not shown anything which could remotely be interpreted as a sphincter and no explanation has ever been offered for the occurrence of such a contraction ring in the midst of the easily passable transverse colon.

The explanation we offer, based on roentgen observations, is that it is the pivoting point of a change in nerve innervation between the vagus and the pelvicus, and on the sympathetic side between the splanchnicus superior and inferior. The point where such change occurs has always been questionable. The majority of writers hold that

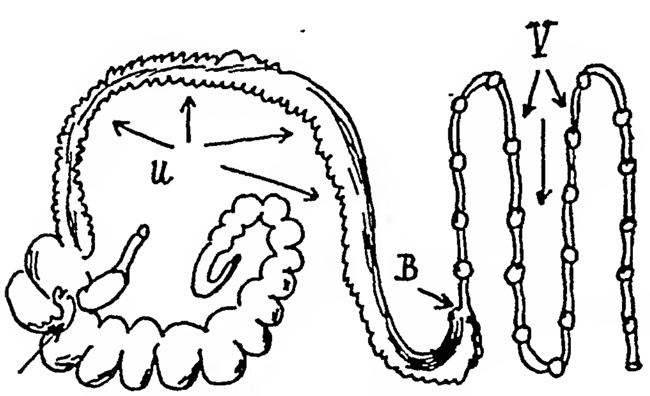

Fig. 4. The division of the colon in cats and rabbits into two units with Cannon's point at *B* (from Garry). *S*, cecum; *U*, proximal colon; *V*, distal colon.

fibers of the vagus nerve down from the celiac plexus follow the vessels and supply the small intestine, the ascending colon, and a questionable part of the transverse colon (Fig. 5). Fibers going from the right, dorsal vagus to the ascending and transverse colon are described by Delmax and Laux, and by Jayle and Cabanac. But just how far down such innervation goes could not be made clear by the anatomical or any other method. That the lower part of the colon and the rectum receives its innervation from the plexus sacralis and the pelvic

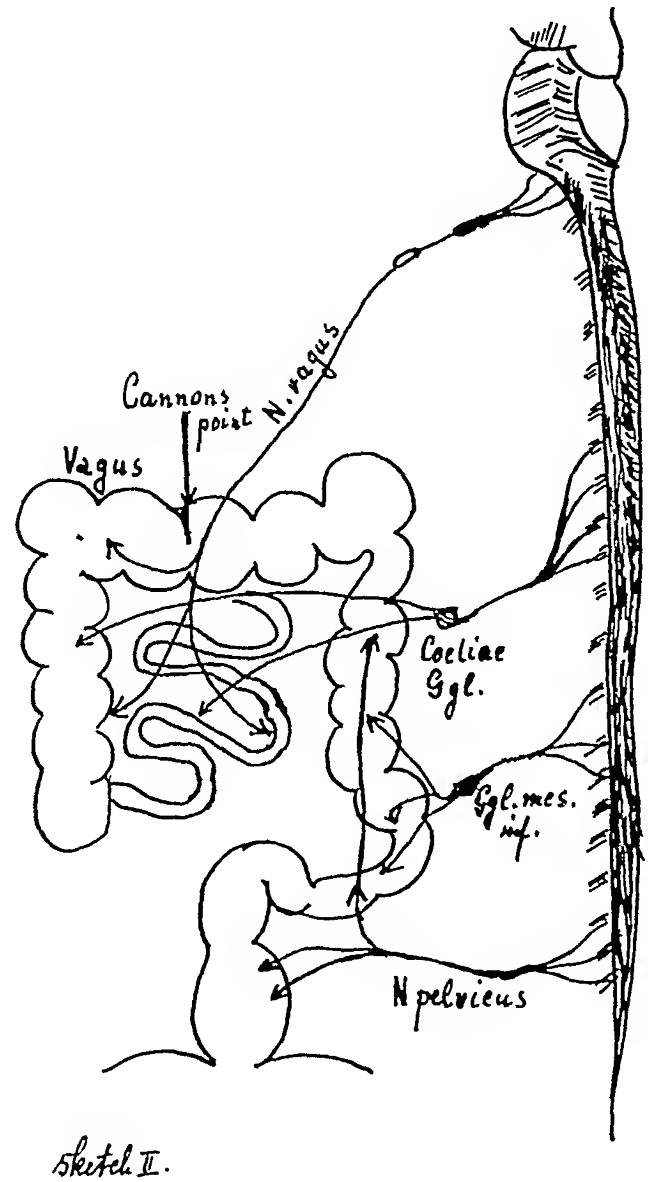

Fig. 5. Schematic drawing of the coordinated or at times antagonistic colon innervation.

nerve is more uniformly acknowledged. The only question and one which has been much debated was the exact location of the innervation. Is it at the rectum, as some authors have thought, or at the ileojejunal flexure, or somewhere in between? Our roentgenological observations make it appear *very probable that Cannon's point is where such a shift takes place.*

Fig. 6. Clear example of demarcation of the two neurological units: the first one (vagus) contracted, the second one of normal width.

Fig. 7. Observation of the reverse process: first neurological entity wide, second contracted, the pivoting point being Cannon's point.

Figs. 8 and 9. Further examples of the antagonistic innervations, transition at Cannon's point.

In order to appear visible in roentgenograms, an antagonism between both spheres of influence must occur; either the distal part has to be wide and relaxed and the proximal part has to be contracted, or the reverse must be the case. The phenomenon of the contraction ring, misinterpreted as sphincter, permits the explanation of a critical reaction at the point of overlapping nerve impulses (Fig. 6–9).

Our roentgenological observation finds its support in embryology where the ascending colon with the large cecum and part of the transverse colon participate in the formation of the umbilical loop and have a common blood supply from the superior mesenteric artery, while the descending colon, a segment of the transverse colon, the sigmoid and the rectum receive their blood supply from the inferior mesenteric artery. It was Testus-Latarget who stated that embryologically the nerve innervation follows the blood supply.

So it is of no more than academic importance, especially for the roentgenologist, how much of the large bowel we call ascending, transverse and descending colon; it is more important to know that there are two distinct nerve and blood supply units, the point of transition of the extrinsic nerve impulses being Cannon's point, as we believe. Not only do peristaltic waves flatten out or reverse themselves at this point, but it is the proximal part of the colon which is the relatively quiet part of the colon, while beyond Cannon's point the great driving movements have their origin.

The knowledge of such a functional antagonism is of great clinical significance: (1) In the explanation of that type of constipation which has been called the ascending colon type. The characteristic of this type of constipation on roentgenograms is the long delay of the barium propulsion beyond the ascending colon. But such a careful observer as Stierlin mentions and stresses that the head of the barium column is frequently arrested somewhat distal to the right flexure.

In order to have normal movement and propulsion, both neurological units have to be correctly charged (to use a term of electricity) with the correct nerve impulse. If the first unit is positive—that is, in contraction—and the second unit wide and receptive, there is no delay at Cannon's point and therefore normal propulsion; if, however, the second unit is contracted and the first unit does not have the necessary strong impulse, we might find the frequently observed and unexplained antiperistalsis and as it subsides we find the resulting constipation of the ascending colon.

The observations of Mony and Vernet that kidney stones are frequently accompanied by constipation and very painful spasm and contraction of the descending and transverse colon are well explained as intestinal reflexes due to the close association between the pelvic nerve and the bladder and kidney innervation causing such a blocking impulse on the second neurological unit.

(2) It is significant that certain affections of the colon, even ulcerative colitis, are frequently confined to the second neurological and blood supply unit. We frequently state that the descending colon is involved, and the ascending colon is normal; but again, quoting an autopsy report from Stierlin's classical work, we find him describing a severe ulcerative colitis: "Ascending colon and proximal half of the transverse colon are normal, ulcers with undermined edges begin at the middle part of the transverse colon." We find many more such examples in the older literature, not so much, however, in recent literature, as these observations of an earlier era have been forgotten. In contrast, tuberculosis involves to a greater extent the first unit and causes spasticity and filling defects (Stierlin's sign), in the entire vagus unit frequently beyond the area of involvement.

(3) It is important in the operation for megacolon. The extent and the localization of the involvement are especially important in the choice of the operation. We know

that the complete elimination of the parasympathetic nerves results experimentally in megacolon. Wade and Royle first used sympathectomy in a ten year old child as treatment for megacolon, while Rankin and Learmonth introduced the operation of the sympathetic fibers collected in the plexus mesenteric inferior and plexus hypogastric, thus doing a partial sympathectomy instead of a radical, if only the upper abnormal colon was involved up to the right flexure; and, as we have demonstrated, somewhat beyond it the sympathetic innervation comes down from the prevertebral ganglia of the sixth lower thoracic segments collected in the celiac ganglion, while the transverse and descending colon, and rectum receive their sympathetic innervation from the lumbar segments collected in the inferior mesenteric ganglion.

Thus we distinguish according to Pässler three groups of megacolon: (1) without involvement of the descending colon, sigmoid, and rectum, *with innervation from the mesenteric plexus, superior*; (2) the descending colon and the sigmoid involved, but not the rectum, *with innervation from the mesenteric plexus, inferior* (with anastomosis from the superior plexus); (3) the megarectum and bladder *with innervation from the hypogastric plexus.*

For the first group Pässler advocates Adson's operation of bilateral resection of the lumbar ganglia, but operation of the mesenteric plexus, inferior and hypogastric plexus is unnecessary. The second group should have the Rankin-Learmonth operation. The third group, involving rectum and bladder, should have resection of the hypogastric plexus.

Thus our roentgenological observation, while confirming the frequent occurrence of a contraction ring at Cannon's point as seen by earlier observers (Boehm, Case), shows just as frequently a different degree of contraction of the colon on both sides of that point and indicates, in our opinion, that this point is not the location of a sphincter or an incidental activated spasm, but an important point of transition of the entire extrinsic innervation.

The general conception of a neurological division of the colon *into two or three* units visible in roentgenograms, which might either harmonize or antagonize one another, appears important to the surgeon as well as to the roentgenologist and internist.

Beyond such immediate usefulness, it is one more observation of a living organ in its function rather than its form. The present-day and future task of the roentgenologist is the study of function rather than of form. Instead of the still life picture of the heart, stomach, and colon we will have in the future the cineroentgenographic and telescopic picture of the complete function of these organs. Disturbed function precedes deformity. Function, on the other hand, has many possibilities of fulfillment under various forms. The colon is especially rich in variations, which to a large extent are efficient in function. If the anatomist Bosch is reported to have said he never saw a normal colon, he was not brought up in the school of the anatomia *animata* of Lamark and Haller. It is *function* which creates and changes *forms*. If we ever hope to make an early diagnosis and institute efficient cure, it will be through finer methods of observing disturbed function roentgenologically and otherwise.

SUMMARY

1. A point in the proximal mid-third of the transverse *colon*, corresponding to the contraction ring in the large bowel of animals, first described by Cannon, is also *found in man.* It is of clinical and roentgenological significance and should be called Cannon's point.

2. Our roentgenological observations indicate that it is the pivoting point of the vagus-pelvicus and of the sympathetic innervation, thus dividing the colon into two distinct neurological units as far as the extrinsic innervation is concerned. The intrinsic innervation follows herein the blood [illegible]

3. To be visible in roentgenograms [illegible]

antagonism between both neurological units is necessary; if the nerve impulses in both divisions are the same, no demarcation can be expected; if they are antagonistic, however, the division is clearly visible. Instead of the antagonism we sometimes see in the case of overlapping impulses a contraction ring caused by intrinsic nerve impulses.

4. Both units may be harmonious or antagonistic. Spastic contraction of the second unit is a frequent cause of constipation in the ascending colon and is best treated by antispasmodics.

5. The proper knowledge of the neurological units is important in differentiation and choice of the operative method of the different types of megacolon.

REFERENCES

1. Adson, A. W. Hirschsprung's disease; indications for and results obtained by sympathectomy. *Surgery*, 1937, *1*, 859–877.
2. Alvarez, W. C. An Introduction to Gastro-Enterology. Paul B. Hoeber, Inc., New York, 1940.
3. Arendt, J. Die Bedeutung des Cannon-Böhmschen Punktes für die funktionelle Gliederung des Dickdarms. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *51*, 508–521.
4. Balli, R. The sphincters of the colon. *Radiology*, 1939, *33*, 372–376.
5. Becker, R., and Oppenheimer, A. Der physiologische Ablauf der Dickdarmbewegung im Röntgenbild. In: Normale und pathologische Funktionen der Verdauungsorgane im Röntbild. G. Thieme, Leipzig, 1931.
6. Boehm, G. Die spastische Obstipation und ihre Beziehungen zur Antiperistaltik. *Deutsches Arch. f. klin. Med.*, 1911, *102*, 431–450.
7. Cannon, W. B. The Mechanical Factors of Digestion. E. Arnold, London, 1911.
8. Cannon, W. B. The movements of the intestines studied by means of the röntgen rays. *Am. J. Physiol.*, 1901–1902, *6*, 251–277.
9. Cannon, W. B. Relation of tonus to antiperistalsis in the colon. *Am. J. Physiol.*, 1911–1912, *29*, 238–249.
10. Case, J. T. X-Ray observations on colon peristalsis and antiperistalsis with special reference to the function of the ileocolic valve. *Tr. Internat. Cong. Med. 1913, Lond.*, 1914, Sect. XXII, Radiol., pt. 2, 11–42.
11. Case, J. T. X-Ray investigation of the colon. *Arch. Roentg. Ray*, 1914–1915, *19*, 375–387.
12. Case, J. T. Basic considerations in roentgen study of intestinal stasis. *Pennsylvania M. J.*, 1914–1915, *18*, 683–704.
13. Corning, H. K. Lehrbuch der topographischen Anatomie für Studierende und Aerzte. Eighth edition. J. F. Bergmann, 1918.
14. Garry, R. C. Nervous control of caudal region of large bowel in the cat. *J. Physiol.*, 1933, *77*, 422–431.
15. Garry, R. C. Responses to stimulation of caudal end of large bowel in the cat. *J. Physiol.*, 1933, *78*, 208–224.
16. Jayle, G. E., and Cabanac, J. Le territoire du pneumogastrique dans l'innervation du tube digestif. *Presse méd.*, 1932, *40*, 200–202.
17. Learmonth, J. R., and Markowitz, J. Studies on the function of the lumbar sympathetic outflow; relation of lumbar sympathetic outflow to sphincter ani internus. *Am. J. Physiol.*, 1929, *89*, 686–691.
18. Learmonth, J. R., and Markowitz, J. Studies on the innervation of the large bowel; influence of lumbar colonic nerves on distal part of colon. *Am. J. Physiol.*, 1930, *94*, 501–504.
19. Müller, L. R. Die Lebensnerven, ihr Aufbau, ihre Leistungen, ihre Erkrankungen. Third edition. J. Springer, Berlin, 1931.
20. Pässler, H. W. Megacolon und Megacystis. J. A. Barth, Leipzig, 1938.
21. Rankin, F. W., and Learmonth, J. R. Section of sympathetic nerves of distal part of colon and rectum in treatment of Hirschsprung's disease and certain types of constipation. *Ann. Surg.*, 1930, *92*, 710–720.
22. Rankin, F. W., and Learmonth, J. R. Present status of treatment of Hirschsprung's disease. *Am. J. Surg.*, 1932, *15*, 219–227.
23. Stierlin, E. Klinische Röntgendiagnostik der Verdauungskanals. J. Springer, Berlin, 1927.
24. Testus-Latarjet. Traité de l'anatomie humaine. Eighth edition. G. Doin & Co., Paris, 1928–1931.
25. Wade, R. B., and Royle, N. D. Operative treatment of Hirschsprung's disease. *Med. J. Australia*, 1927, *1*, 137–141.

SKELETAL METASTASES IN CANCER OF THE BREAST

STUDY OF THE CHARACTER, INCIDENCE AND RESPONSE TO ROENTGEN THERAPY*

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"AS a palliative method, radiation causes complete regression of many local recurrences. Some of the most striking results are seen in the control of bone metastases, in which pain is relieved, the bone structure restored, and life prolonged" (Ewing).[5]

Too many cases of cancer of the breast with skeletal metastases are considered totally hopeless and doomed to death at an early date no matter what one might attempt in the way of treatment. Such an attitude seems to be unjustifiable.

A critical study of a series of consecutive cases of cancer of the breast showing unquestionable evidence of osseous neoplastic involvement, with particular reference to the value of palliative therapy, is reported here in support of this argument.

Since 1938, 180 cases of cancer of the breast, in various stages, have been treated in the Department of Radiology at the Royal Victoria Hospital. Among these cases, 37 showed definite evidence of skeletal metastases, roentgenographically, with a total mortality of 24 up to the present time. As the majority of the whole series are still living, we do not believe sufficient time has elapsed to use those figures to establish a morbidity rate with skeletal metastases. Ewing[5] has reported that Gross found the incidence to be 20.5 per cent in a series of 423 autopsies, while Kaufman found 53.0 per cent in 63 autopsies. I am inclined to feel that the first figure is too low and the latter too high; the mean would probably be close to reality. Repeated routine roentgenographic examinations in a large series of cases should prove to be a definite adjunct to postmortem examinations in determining such morbidity rate.

As one surveys the literature, very few studies of large series of cases of skeletal metastases from cancer of the breast are to be found in which the effect of roentgen therapy has been discussed. In 1931, Lenz and Freid[9] published their findings in 81 cases. Geschickter and Copeland[7] reported the results they obtained in 34 cases. The best paper on the subject, in my opinion, is that of Wulff,[11] of Lund, Sweden, dealing with 44 cases treated between 1929 and 1937. The only criticism that one could make with regard to Wulff's paper is that he included the cases of patients still living, with the result that some of his figures were not final. To avoid that pitfall, I have confined the present study to an analysis of but 24 of the 37 cases which have been treated in the Department of Radiology of the Royal Victoria Hospital since 1938, and have not included any who still survive.

CLASSIFICATION OF CASES

Bearing in mind that a very exact and accurate classification of cases is essential in the study of carcinoma of the breast, considerable care and attention has been devoted to that matter. The old classification of Steinthal has been discarded in favor of that of Portmann[10] which is more accurate and logical, as it is based not only on clinical, but also on pathological findings. This permits a more precise appreciation as to the extent of the disease. For example, the axillary glands are recorded as involved only if so demonstrated by pathological sections. Portmann's classification also allows for consideration of distant metastases, without regard to the degree of involvement of the breast alone. The details of that classification are as follows:

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Group I

(*a*) *Tumor* definitely localized to the breast and movable;
(*b*) *Skin* not involved;
(*c*) *Metastases* not present in axillary lymph glands.

Group II

(*a*) *Tumor* localized to the breast and movable;
(*b*) *Skin* not affected (or only very slightly edematous or ulcerated);
(*c*) *Metastases* present in axillary lymph glands but few involved.

Group III

(*a*) *Tumor* diffusely involving the breast;
(*b*) *Skin* involved (edematous, ulcerated), multiple nodules);
(*c*) *Metastases* to numerous axillary lymph glands or to other tissue (supraclavicular nodes, lungs, bones, etc.).

Cases have been classified as indicated in Table I according to the clinical, pathological and roentgenographic findings. As one would logically expect, it is in the Group II and III cases that skeletal metastases are most frequent. One case could not be classified due to the lack of complete data.

Table I

CLINICAL AND PATHOLOGICAL CLASSIFICATION (PORTMANN)

Group	No. of Cases	Per Cent
I	3	12.5
II	9	37.5
III	11	45.8
Unclassifiable	1	4.2
Total	24	100.0

LOCATION OF THE PRIMARY TUMOR

It is the general experience that the left breast is more often involved than the right. Our series is in accord with this, since in 13 of the 24 patients the primary lesion was in the left breast.

Not a single case was bilateral from the onset, although extension to the opposite breast occurred in 5 cases. Two of these presented the so-called "inflammatory" type of carcinoma. Another had a right radical mastectomy sixteen years before the appearance of cancer in the left breast without any evidence of local recurrence or distant metastasis in the interval.

For the purpose of the present discussion, it is considered that any cancer developing in the opposite breast ten years or more after the first is an entirely new growth having no direct relationship whatsoever with the previous contralateral carcinoma. For the above reason, in our analysis the skeletal metastases are assumed to be related only to the carcinoma of the left breast in the case just mentioned.

So far as I can determine, there is no appreciable connection between the location of the primary tumor in the breast itself and the incidence of skeletal metastases. In other words, the frequency of dissemination of neoplastic cells to bone bears no significant relationship to the quadrant of the breast in which the primary tumor may have originated.

PATHOLOGY

Biopsy of the primary tumor was taken in 5 cases only. However, unquestionable proof of cancer was obtained in all the other cases from the microscopic examination of surgical specimens. Our pathological material does not permit us to infer that skeletal metastases are more frequent with one histopathological type of tumor than with another. The rate of growth, degree of anaplasia, and extent of the pathological process in the breast and its draining lymphatics seem to be more indicative histopathological findings as to the probability of subsequent or ultimate skeletal involvement than the type of tumor. Lenz and Freid[9] attach primary importance to the pathological grading as an indication of the degree of malignancy by a correlation of grading on the one hand, and the prognosis or survival, on the other.

The histopathologic proof of osseous metastases has become available in only 3 cases by means of postmortem examination. For all our patients roentgenographic evidence as well as the clinical course was

required to establish a diagnosis of skeletal metastases.

AGE FACTOR

The age factor does not seem to play any important rôle in regard to the incidence of bone lesions. The age varies from twenty-four to seventy-seven years at the apparent onset of the tumor. The average age for all cases was 44.4 years.

Table II

GROUPING OF PATIENTS ACCORDING TO AGE AT ONSET OF TUMOR

Decade	No. of Cases	Per Cent
20–30	2	8.5
30–40	6	25.0
40–50	10	41.3
50–80	5	21.0
Age unknown	1	4.2
Total	24	100.0

Grouping patients by decades of age (Table II) does not indicate in any way that metastases to bone occur more often in younger than in older patients. The rate of frequency merely follows the usual curve of incidence of cancer of the breast. Just as cancer of the breast is more common in the age group forty to fifty than in any other, it is during that decade that we find the highest incidence of skeletal metastases.

INTERVAL BETWEEN ONSET OF PRIMARY GROWTH AND ROENTGENOGRAPHIC EVIDENCE OF SKELETAL METASTASES

The exact date of onset of any cancer is almost impossible to determine. Nevertheless, if we take as a starting point the time at which a patient has first noticed the presence in the breast of a growing tumor on the one hand, and when roentgenographic examination has first demonstrated evidence of skeletal metastases on the other, we obtain some interesting data.

The interval between the apparent onset of the breast tumor and that of neoplastic invasion of bone varied from three months to seventeen years. The mean interval for all cases without discrimination is 45.3 months. However, if we exclude 2 cases for which the interval has been exceptionally long, that is nine and seventeen years respectively, we find a mean interval of thirty-four months. The latter figure, I believe, is more factual than the former, and should be retained in preference. Table III also indicates that skeletal metastases would appear to occur earlier in the twenty to thirty year age group than in any other. This was to be expected as we know that cancer in that decade of life is usually more malignant and evolves more rapidly.

Table III

AVERAGE INTERVAL IN MONTHS BETWEEN KNOWN ONSET OF PRIMARY GROWTH AND ROENTGENOGRAPHIC EVIDENCE OF SKELETAL METASTASES

Interval varies from 3 months to 17 years

Decade	Months
20–30	22.0
30–40	42.0
40–50	46.3
50–80	46.2

Gross mean interval: 45.3 months
Net mean interval: 34.0 months

Analysis of the above data permits us to substantiate the exactness of the following rule expressed by Wulff:[11] the longer the interval between the apparent onset of the primary growth and that of the skeletal metastases, the longer the survival.

INCIDENCE AND ORDER OF INVOLVEMENT OF BONES

The predominance of involvement of certain bones in cancer of the breast is well known. Handley[8] long ago demonstrated that it is due to anatomical conditions, mainly in relationship to the regional mode of extension of that particular type of neoplasm.

Table IV indicates the rate of incidence of metastases to certain parts of the skeleton in our series of cases. There seems to be a close parallel between the rate of incidence and the order in time in which the same bones are involved. Generally speaking, our figures are relatively in accordance with those published by others. From this analysis I wish to emphasize the neces-

sity of a systematic and careful investigation for bone involvement in cancer of the breast especially in pelvis, lumbosacral vertebrae, ribs, dorsal vertebrae and femora. Skeletal metastases below the elbow and knee have not been found in the present series. Although a few cases have been reported in the literature by Lenz and Freid,[9] Copeland,[4] Carnett and Howell,[2] as well as Clarkson and Barker,[3] they are exceptional.

Table IV

INCIDENCE AND ORDER OF INVOLVEMENT OF VARIOUS BONES

	Per Cent		Per Cent
Pelvic bones	75.0	Cervical vertebrae	33.0
Lumbosacral vertebrae	71.0	Skull	25.0
Ribs	71.0	Scapula	25.0
Dorsal vertebrae	62.5	Humerus	12.5
Femur	54.0	Clavicle	8.3
		Sternum	8.3

ROENTGENOGRAPHIC ASPECT OF OSSEOUS LESIONS

Bone metastases from cancer of the breast when first discovered are sometimes single, but more often multiple lesions. Eventually they nearly always become multiple.

There are three general types:

(1) The *osteolytic* type seems to be by far the most common when first discovered, since we observed that character of bone change in 75 per cent of the cases. The lesion is characterized by areas of bone erosion with complete destruction of trabeculae developing in either the spongiosa or the cortex, depending upon the bone involved. The destructive process may be more or less diffuse in appearance, or be sharply circumscribed as though the bone had been punched out (Fig. 1*A*, 2*A*, 3*A*, 4*A* and 8*A*).

(2) The *osteoblastic* type presents an entirely different picture. Roentgenograms show areas of markedly increased density in which the bone trabeculae are no longer identifiable and seem to have been replaced with abundant calcium salts and sclerotic tissue. The true osteoblastic type has been found as the first manifestation of skeletal metastasis in only 8.3 per cent of our patients (Fig. 5, 7*A*, 8*A* and 9).

(3) The *osteolytic-osteoblastic* type of lesion is an intricate blending of the other two. It shows on roentgenograms as islands of bone destruction surrounded with rings or strands of very dense and coarse bone. We have observed that appearance on the initial roentgenographic examination showing distant neoplastic involvement in 16.7 per cent of the cases (Fig. 6).

We may find any of the three types of lesions in the same patient on subsequent examination throughout the course of the disease.

Table V

ROENTGENOGRAPHIC ASPECT OF OSSEOUS METASTATIC LESIONS

Type of Lesion	No. of Cases	Per Cent
Osteolytic	18	75.0
Osteoblastic	2	8.3
Osteolytic-osteoblastic	4	16.7
Total	24	100.0

Wulff,[11] basing his opinion on the work done by Hellner and Axhausen (who demonstrated that microscopically every bone tumor either primary or secondary is at the beginning osteolytic in type), has written that if all cases of skeletal metastases were examined roentgenologically early enough, and if the neoplastic foci were sufficiently large the osteolytic type of lesion would always be found. The other types would only show later in the course of the disease. Wulff[11] also postulates that the osteoblastic predominance in any lesion is an indication that the bone lesion is growing slowly. This agrees with our observations and experience.

DIAGNOSIS

The majority of the cases have clinical symptoms which give rise to suspicion that metastases exist in bone. The usual complaint was "rheumatic" or "neuralgic" pains, often of the referred type. In some cases there was no complaint of pain, but a thorough physical examination for follow-up purposes had revealed the presence of

local tenderness. Subsequent roentgenographic examination demonstrated definite evidence of secondary neoplastic lesions. As with other authors, we often observed that sometimes pain precedes by several months the roentgenographic confirmation of skeletal metastases. As in Lenz and Freid's series,[9] we also noticed that whenever metastases develop in regions of the skeleton where the natural body weight and muscular traction are more pronounced the pain is sharper and comes on earlier.

In a few exceptional cases which manifested no clinical symptoms or signs whatsoever of bone metastasis, the diagnosis was established by means of the routine roentgen examination made to determine whether or not the skeleton was involved. In any patient with local recurrences or regional metastases, the possibility of bone involvement by neoplastic cells in the process of dissemination must be considered and searched for.

Occasionally the incidental finding of an unsuspected skeletal metastatic lesion will lead to the discovery of cancer of the breast itself. One of our patients had been complaining of sciatic pain, and for eight months before coming to the Royal Victoria Hospital had received treatment without any improvement. Roentgenograms made on admission demonstrated in the pelvis and right femur bone lesions resembling metastases. Search for the primary revealed a small cancer in the right breast.

PRINCIPAL ASSOCIATED METASTASES

In 17 of the 24 cases, i.e. 62.5 per cent, skeletal lesions were the first metastases to be found and the only ones demonstrable for some time. Two patients only, that is 8.3 per cent, never at any time showed any appreciable evidence of metastases elsewhere save in the skeleton. From a careful study of the history of each individual case, I have gained the definite impression that so long as certain other metastases are not associated with those to bone, the immediate prognosis is not as bad as one would be inclined to feel. It seems that the association of pleuropulmonary or hepatic metastases causes the prognosis to deteriorate progressively. Cerebral metastases, except in generalized and rapidly evolving carcinomatosis, do not necessarily mean that the end is approaching. One such patient survived in relatively good condition for almost a year in spite of cerebral and vertebral metastases with the help of palliative roentgen therapy. The final and rapid retrogressive course occupied only a month.

It is not possible to establish any pattern or order in time of incidence of the principal associated metastases in contradistinction to the pattern of skeletal involvement.

The rate of incidence has been tabulated in Table VI.

TABLE VI

PRINCIPAL ASSOCIATED METASTASES

	Per Cent
Cutaneous	[illegible]
Pleuropulmonary	[illegible]
Mediastinal and parasternal nodes	[illegible]
Supraclavicular nodes	[illegible]
Cerebral	[illegible]
Hepatic	[illegible]

TREATMENT OF THE PRIMARY TUMOR

One may well wonder if there can be any relationship between the incidence of skeletal metastases and any selected method of treatment of the primary in any [illegible] group. In our series, such proved to be impossible to establish in view of the fact that too many varieties and combinations of treatment of the primary tumor had been used.

TABLE VII

TREATMENT [illegible]

Surgery	No. of Cases	Roentgen Therapy
Inoperable	[illegible]	Only
Radical mastectomy	[illegible]	Pre-operative
Simple mastectomy	[illegible]	Post-operative
Excision of tumor	[illegible]	[illegible]
	[illegible]	
	[illegible]	

However, a patient in [illegible] sidered absolutely inoperable [illegible] less by the surgeon, and [illegible] with irradiation only, [illegible] twice as long as the other [illegible]

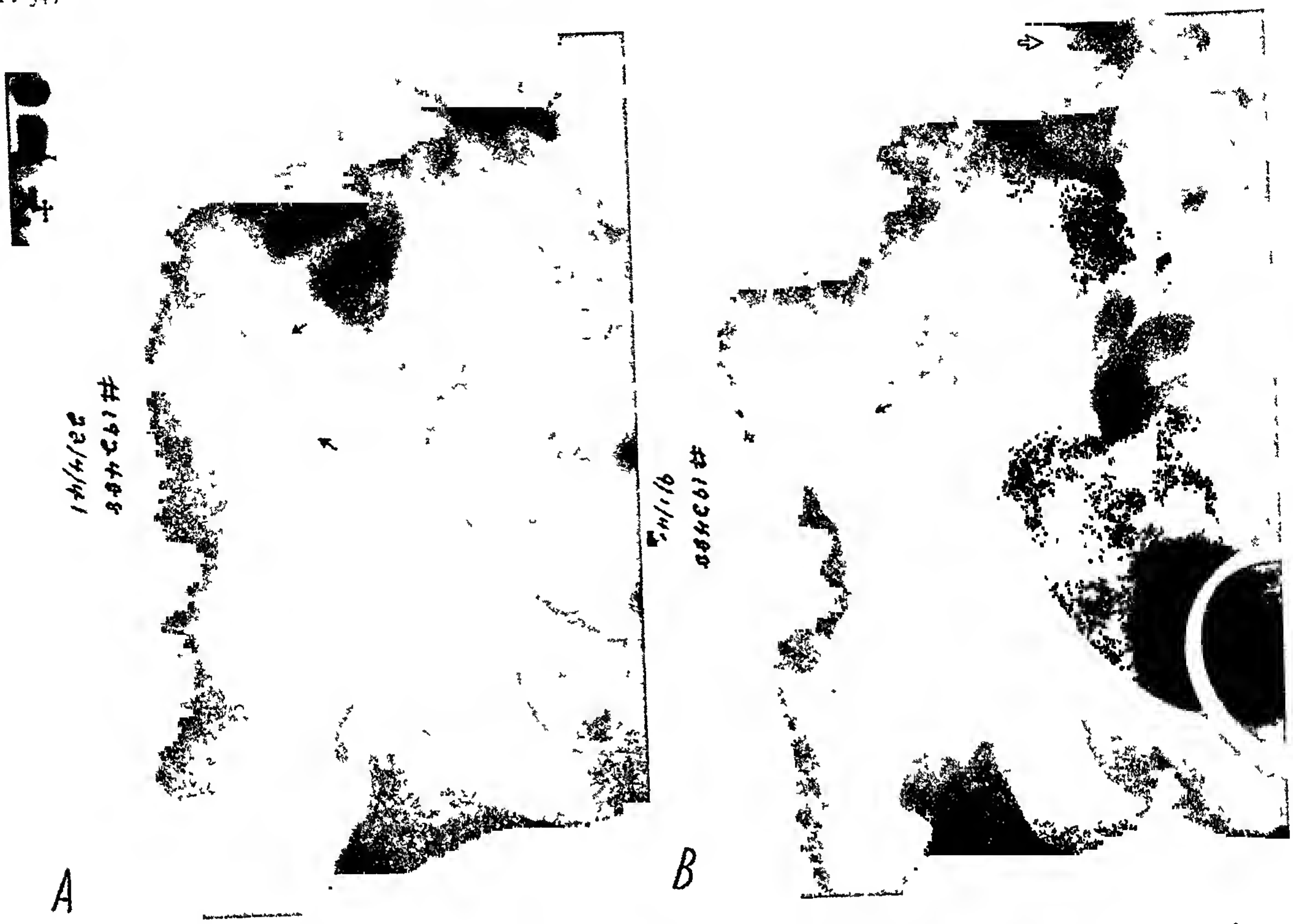

FIG. 1. Case I. *A*, osteolytic lesion in the right ilium as indicated by black arrows. *B*, osteoblastic repair seven months after roentgen therapy (6,800 r).

group but had both subjective and objective improvement of skeletal metastases. This, in my opinion, is an argument against the use of surgery in patients of that group, and suggests the value of suitable roentgen therapy.

TREATMENT OF SKELETAL METASTASES AND RESULTS

Roentgen therapy was administered as a palliative measure for the skeletal metastases to 23 of the 24 patients. The following technical factors were used: 200 kv., 50 cm. focal skin distance, and 1.0 or 2.0 mm. Cu filter. Depending on which filter we used, the half-value layer was 1.35 or 2.00 mm. Cu, and the effective wave length 0.13 or 0.11 A° respectively. The size and number of fields varied with the region to be treated. Daily doses of 150 r per field were given, two fields usually being treated at each session, up to a total dose of 2,000 to 4,000 r, measured in air.

The results of treatment can be classified in three categories (Wulff):[11] First, the negative results in which neither relief of pain nor improvement of the roentgenologic signs was accomplished during the weeks and months following administration of the treatment (Case V). Survival periods for this group of cases varied between three and twenty-four months, the average being 9.3 months. Eight of our patients, i.e. 34.8 per cent, fall in this category. Incidentally, we noted that the same patients did not respond more favorably to any other form of therapy.

The second category is that in which a definite subjective improvement was observed. Pain was obviously relieved, as a rule, after the first four to six doses, and subsequently disappeared completely for weeks and months. In many of these cases further roentgen irradiation was given successfully two or three times for recurrent symptoms. Nevertheless, no appreciable

change in the initial roentgenologic aspect of the bone lesions could be demonstrated. In spite of the relief of pain, the progression of the disease would not seem to have been materially affected or checked, although the average survival of 13.6 months for this group was longer than the former. Individual survival periods varied between six and twenty-five months. Nine of our patients, i.e. 39.1 per cent, showed subjective improvement only. If, on the other hand, we include patients of the following category who also experienced subjective improvement, we arrive at a total of 15, or 65.2 per cent, of all the cases.

The third, or last, category, and perhaps the most interesting, includes the cases in which not only pain was relieved but also unquestionable roentgenographic evidence of objective improvement was observed. Further extension of the initial destructive bone lesions stopped and the area gradually became denser (Fig. 1, *A* and *B*), with, in some cases, eventual excessive recalcification (Fig. 2, *A*, *B* and *C*). Often, as also observed and described by Adair[1] and by Wulff,[11] the punched out areas filled progressively from the periphery toward the center, the latter remaining radiolucent for a longer time before finally filling with calcium salts (Fig. 4, *A* and *B*). In other words, depending on its initial type, the skeletal lesion passes successively from the osteolytic to the osteolytic-osteoblastic phase and then may take on the osteoblastic appearance. In a few cases, as emphasized by Wulff, the bone reaction goes one step farther, and apparent healing occurs (Fig. 3, *A*, *B* and *C*). The lesion which either initially appeared or, following roentgen treatment, gradually became osteoblastic in type, may regress and decrease in density with eventually partial to complete reorganization of bone trabeculae (Fig. 7, *A* and *B*, and 9, *A* and *B*). Roentgenologically, we have observed that it usually takes at least two months, from the beginning of administration of roentgen therapy, before any definite evidence of bone repair appears. Optimum healing may require an interval of six to twelve months, as in Case III (Fig. 3, *A*, *B* and *C*). Six cases, or 26.1 per cent, were to be classified in this third category. The average survival is

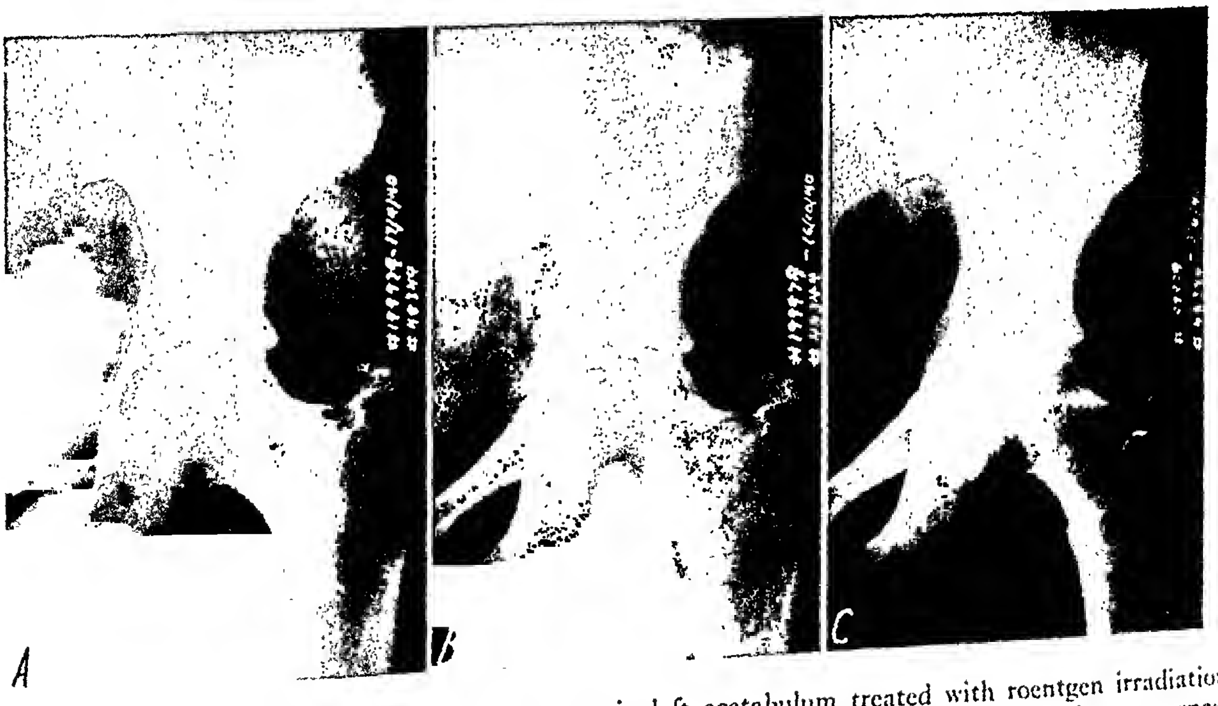

Fig. 2. Case II. *A*, April, 1940. Osteolytic process in left acetabulum treated with roentgen irradiation (5,450 r). *B*, October, 1940. Partial repair, the lesion now having the osteolytic-osteoblastic appearance. *C*, June, 1941. Further improvement of bone lesion which has become osteoblastic. Patient remained free from pain after treatment.

Fig. 3. Case III. *A*, May, 1939. Large destructive metastasis in shaft of right femur. Roentgen therapy was used with a total dose of 1,500 r only. *B*, July, 1940. Complete and exaggerated repair reaction at the osteoblastic stage. *C*, January, 1940. *Restitutio ad integrum*, which has persisted.

17.5 months while the individual cases vary from eight to twenty-nine months (Cases I, II, III, IV, VI and VII).

At this point we must state that roentgen irradiation may not deserve all the credit for objective improvement observed following this treatment. We have found many instances in which lesions spontaneously passed from the osteolytic to the osteoblastic phase (Fig. 5). All one can say in regard to the rôle of irradiation is that it probably reduces or prevents further activity of the neoplasm, with the resultant normal reparative reaction in the involved bone. Although spontaneous *restitutio ad integrum* in bone metastases of such cases may occur, we believe that beyond the osteoblastic phase any appreciable degree of bone regeneration may be attributed to the irradiation administered.

As an additional therapeutic measure, in 3 cases the pituitary and ovaries were given

Fig. 4. Case IV. *A*, multiple punched out areas of bone due to metastases in iliac bones and left sacroiliac region. *B*, marked osteoblastic reaction indicating healing seven months after roentgen therapy (4,000 r).

Fig. 5. Case iv. Osteoblastic reaction which occurred spontaneously, i.e. without roentgen irradiation, and followed osteolytic changes in the fourth dorsal vertebra.

roentgen irradiation without any appreciable effect on the evolution of the metastatic lesions in bone.

If we analyze the results for the different groups (Table viii), we find that 2 of the 3 cases in Group i have benefited by irradiation; in Group ii, 8 (Cases i, ii, iv and vii) out of 9, although in Group iii, only 5 patients out of 11 (Case vi) obtained some degree of improvement. Complete palliation often is not possible because of the widespread disease in this group. The patients classified in Group ii responded better than those in the other groups, since 4 of 9 were not only relieved of their pain but also showed roentgenographic evidence of bone repair.

Fig. 6. Case v. Extensive osteolytic-osteoblastic changes involving the thoracic cage, spine and shoulder girdle. Roentgen therapy was of no avail.

Table VIII

DEGREE OF PALLIATION EFFECTED BY ROENTGEN THERAPY

(23 Cases)

	No. of Cases					Apparent Survival in Months
	Group			Total	Per Cent	
	I	II	III			
None	1	1	6	8	34.8	9.3
Subjective improvement	1	4	4	9	39.1	13.6
Subjective and objective improvement	1	4	1	6	26.1	17.5
Total	3	9	11	23	100.0	

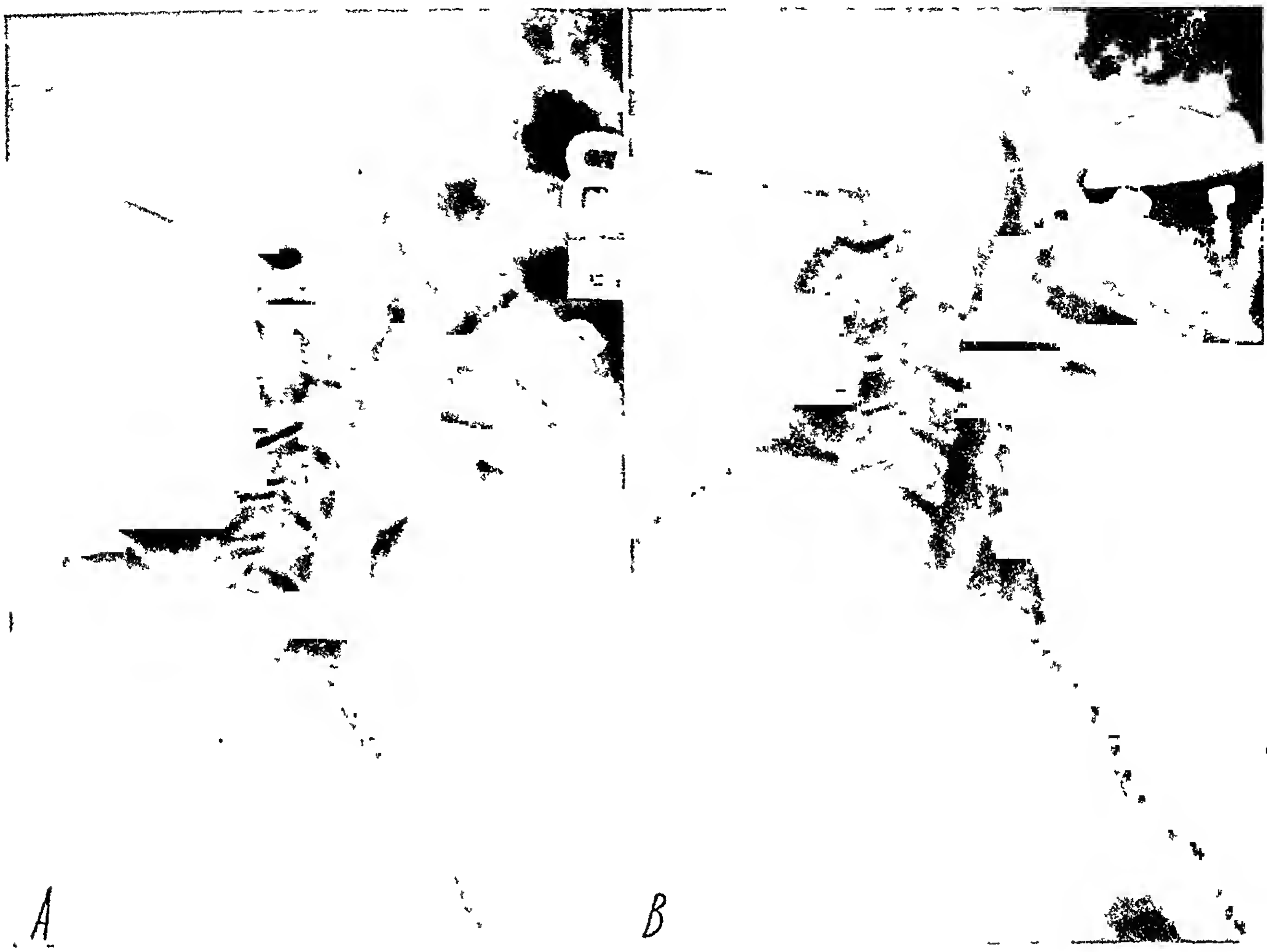

Fig. 7. Case vi. *A*, May, 1939. Third cervical vertebra initially showing a pure osteoblastic appearance. Patient had been complaining of occipital pain for a year. *B*, March, 1941. Partial regression of osteoblastic reaction with some reorganization of bone trabeculae, following five series of roentgen treatments.

CASE REPORTS

Case i. Mrs. M. P., aged seventy-two, found a lump in her right breast in July, 1938. Radical mastectomy on October, 1938, revealed carcinoma solidum scirrhous with involvement of axillary glands (Group ii). Postoperative roentgen therapy of breast (3,500 r) was given. Pain in both iliac bones and right hip in April, 1941, when roentgenograms showed a large osteolytic lesion in right ilium and other lesions in dorsolumbar vertebrae and right femur. Roentgen irradiation with 6,800 r to right ilium induced complete relief of pain in less than two weeks. Cutaneous metastases (breast) in October, 1941, were treated locally with radium. Films in January, 1942, demonstrated marked bone repair in right ilium, but extension of metastases to ribs, dorsolumbar spine and left femur. Irradiation of spine and left femur again afforded relief of pain. Although invalided, she was moderately comfortable from July, 1942, until her death on November 21, 1942.

Case ii. Mrs. A. H., aged forty-four, discovered a small nodule in the left breast in June, 1937. Radical mastectomy without dissection of axilla was done a month later, followed by postoperative roentgen therapy to the breast area, and irradiation of the ovaries to induce an artificial menopause. Pain in the left hip preceded by several months the demonstration of an osteolytic lesion in the left acetabulum in April, 1940. A total dose of roentgen radiation of 5,450 r afforded complete relief of pain. A roentgenogram made in October, 1940, showed bone repair and changes to the osteolytic-osteoblastic type. However, by June, 1941, progressive increase in density of the left ilium to a definite osteoblastic character was accompanied by the development of other metastases in the lumbar spine and left femur. On October 2, 1941, without evidence of any local recurrence in the breast area or return of pain, she died of hepatic metastases after being in bed for only two weeks.

Case III. Mrs. A. T., at the age of thirty-seven, had a radical mastectomy in 1929 for cancer of the left breast. In November, 1938, and January, 1939, she was treated surgically for recurrences in the scar. Later, in March 1941, the first skeletal metastases were found in the ribs and dorsal vertebrae with partial collapse of the fourth dorsal. The bone lesions were osteolytic in type, becoming osteoblastic after irradiation. Pain developed in the right knee in May, 1939, at which time a roentgen examination revealed an area of marked destruction of bone in the proximal half of right femoral shaft. This lesion was irradiated with a dosage of 1,500 r, and pain disappeared completely. Seven months later roentgenograms made elsewhere showed complete repair and healing of that lesion. Other skeletal metastases have been treated from time to time. She is still living and comfortable, four years after the first skeletal metastasis was found (sixteen years after operation), in spite of other cutaneous recurrences over the sternum.

Case IV. E. C., female, unmarried, at the age of forty-two had a tumor in right breast for three years before a radical mastectomy in March, 1936 (Group II). Pain in hips on standing came on six months later, and roentgen evidence of multiple osteolytic lesions in the pelvic bones was found. Roentgen therapy (4,000 r) induced early and complete relief of pain followed by complete repair with marked osteoblastic reaction by May, 1937. In February, 1938, further involvement was found in the dorsolumbar spine, especially osteolytic-osteoblastic in the third lumbar. The fourth dorsal was showing signs of collapse and presented the osteoblastic type of lesion. Roentgen therapy again caused subjective and objective improvement. Patient died with general carcinomatosis, including cerebral metastases, on February 17, 1939, having had intractable pain since October, 1938.

Case V. Mrs. V. S., at the age of thirty-one, December, 1937, felt a small tumor in her left breast. Second small mass in April, 1938. Preoperative roentgen irradiation (6,000 r) after the latter, and radical mastectomy was followed sixteen months later by constricting thoracic pain and cutaneous metastases. Extensive osteolytic-osteoblastic lesions were present in the bony thorax and shoulder girdles. No improvement of any kind was afforded by the irradiation. Death occurred December 31, 1939.

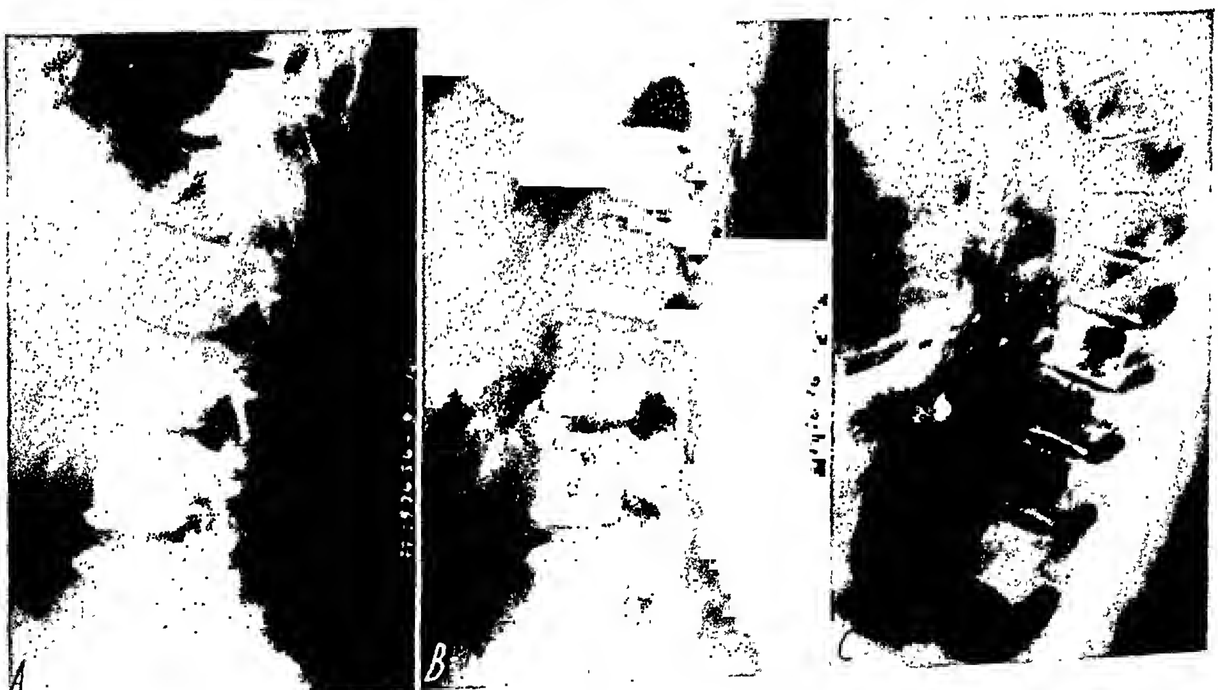

Fig. 8. Case VI. *A*, November, 1940. Osteoblastic type of lesion in the twelfth dorsal vertebra and osteolytic process in second lumbar. *B*, March, 1941. Following the administration of 1,950 r, there is now evidence of remarkable bone repair and reorganization of trabeculae in second lumbar. *C*, March, 1941. The twelfth dorsal vertebra also responded to treatment, as is evident from partial regression of the initial osteoblastic reaction.

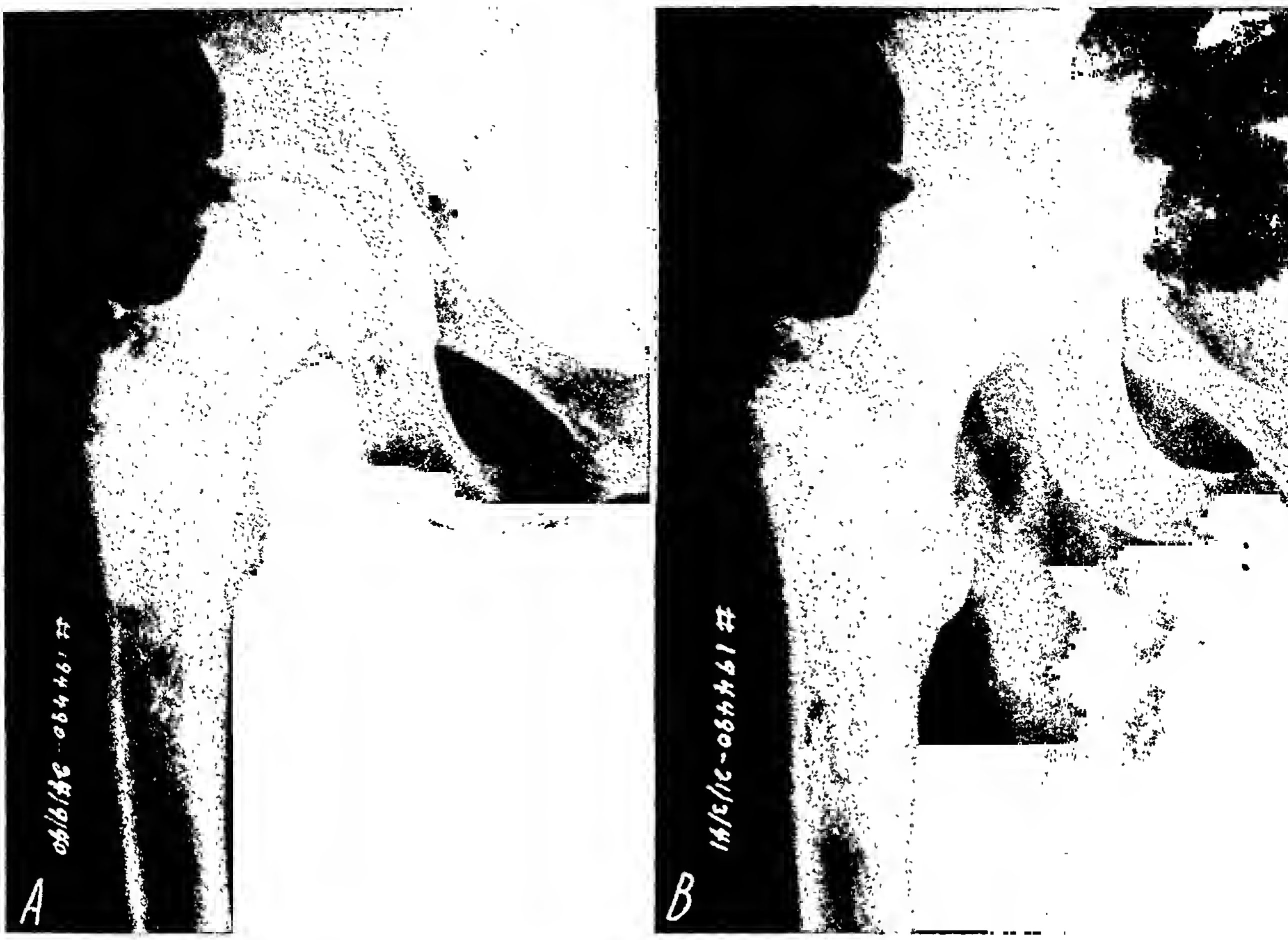

Fig. 9. Case vii. *A*, September, 1940. Osteoblastic lesion in proximal end of right femur treated with roentgen irradiation (4,100 r). *B*, March, 1941. Decreased density and normal character of trabeculae indicating bone repair.

Case vi. Mrs. J. McR., then aged forty-four, first noticed a tumor in her left breast. In May, 1939, she first consulted the Outdoor Clinic for headache and occipital pain of one year duration. No lesion was found in the skull, but the third cervical vertebra was markedly osteoblastic. The breast tumor was treated with roentgen irradiation only, as the tumor was considered inoperable. Roentgen therapy to the cervical spine temporarily relieved the pain. Recurrence of the pain required multiple series of treatments. Two years later the third cervical was smoother in outline and not as dense. In November, 1940, she complained of lumbosacral pain, and an osteolytic lesion of the second lumbar as well as an osteoblastic lesion of the twelfth dorsal was found. Irradiation to the dorsolumbar area relieved the pain, and by March, 1941, there appeared to have been complete repair and healing in the second lumbar, while the twelfth dorsal had decreased in density and showed better texture. She died on June 30, 1941, exact cause unknown.

Case vii. Mrs. B. M. had a small mass in the right breast in 1931, at the age of thirty-eight. A radical mastectomy was performed a month later. In 1938 a cutaneous recurrence was excised and the region irradiated. Pulmonary metastases developed in June, 1940, and were treated by roentgen irradiation, with improvement. An osteoblastic lesion of the right femur appearing in September, 1940, with pain, was given roentgen therapy (4,100 r), followed by complete relief of pain. Bone repair in the nature of decreased density and more normal character of trabeculae had been achieved by March, 1941. She died in September, 1941, exact cause unknown.

Case viii. Mrs. U. B. first noticed the eczematoid appearance of the skin over the left breast about August, 1934, at the age of fifty-five. This ulcerated six months later. In December, 1936, when she first consulted her physician, the tumor was large and considered inoperable. Biopsy confirmed the diagnosis of

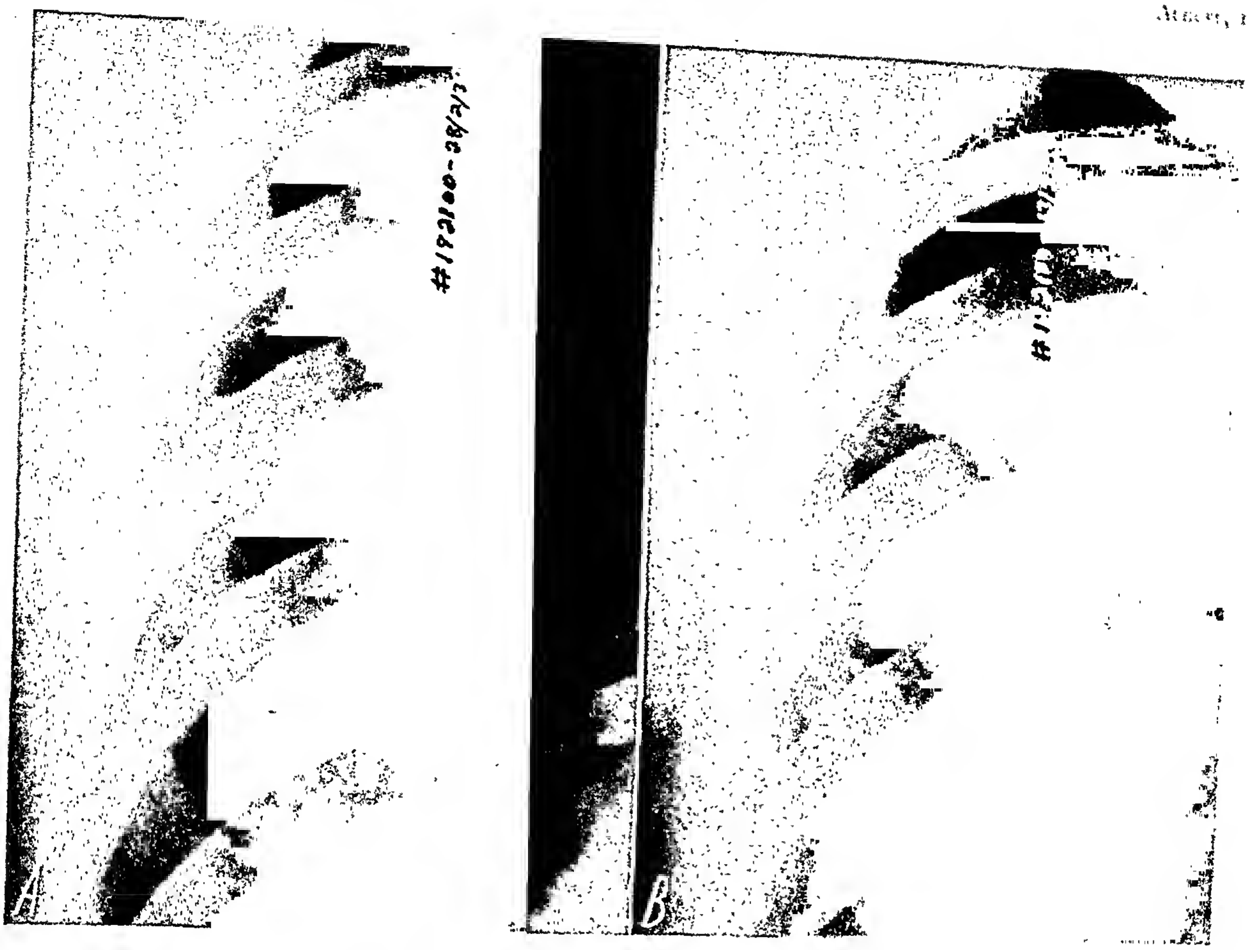

Fig. 10. Case viii. *A*, February 28, 1939. Roentgenogram showing early repair of a pathological fracture of the sixth right rib, which occurred in January, 1939. Roentgen therapy to right thorax (2,700 r). *B*, March 14, 1939. Healing is progressing rapidly with formation of an exuberant callus.

carcinoma (carcinoma solidum). The local tumor was treated with both radium and roentgen irradiation. In September, 1937, she complained of pain in the right hip. An osteolytic metastasis in the right femur was found, and subsequently given 6,000 r. Later the pelvic bones, vertebrae, ribs and left humerus showed metastases. Pathological fracture of the right sixth rib occurred in January, 1939, at the same time as pleural metastases. Irradiation of the right thorax (2,700 r) induced a good healing of the fracture. She died in July, 1939, having had constant pain and distress in the terminal week.

SURVIVAL WITH SKELETAL METASTASES

An attempt has been made to establish the survival rate in months for the various age groups, first, from the apparent onset of cancer, second, from the time of treatment of the primary tumor, and third, from the time of appearance of metastases to bone.

It seems that the age period cannot be used as a prognostic base for survival either from the time of any form of treatment of the primary tumor or from that of the appearance of secondary lesions in bone. Also, the lapse of time between the apparent onset of the tumor in the breast and the application of any form of treatment of the primary tumor does not offer any indication as to the probable survival after the demonstration and treatment of skeletal metastases.

Table IX

SURVIVAL IN MONTHS FROM:

Decade	Onset of Primary Tumor	Treatment of Primary Tumor	Appearance of Metastases
20–30	33.0	18.0	12.8
30–40	53.1	30.7	9.6
40–50	65.5	31.3	17.4
50–80	55.2	45.2	[illegible]
Average survival	52.9	33.4	[illegible]

Some further interesting information may be gained from the data given in Table IX. The average survival from the appearance and treatment of skeletal metastases for all cases indiscriminately is 13.6 months. Individual survivals range from between three and thirty-three months. The mean survival of the patients who were in the forty to fifty decade in 17.2 months. This figure is obviously higher than in any other age period. In view of this potential increased survival period, should such patients with bone metastases from carcinoma of the breast be abandoned to their fate without benefit of such relief and palliation which is available to them?

Table X

SURVIVAL IN MONTHS IN VARIOUS CLINICAL GROUPS

Group	Interval between Onset of Primary Tumor and Metastases	Survival with Skeletal Metastases
I	18.3	7.4
II	37.7	15.2
III	35.5	14.6

The average survival in patients of the twenty to thirty age period was 12.5 months, which I am inclined to believe is somewhat high for that particular group. That may be due to the fact that we have only 2 patients falling in that decade of life, one of them having survived for twenty-two months. Lenz and Freid, however, believe that the prognosis is not necessarily grave in young individuals. Their figures, as ours noted above, suggest that the survival period with skeletal metastases depends more on the degree of malignancy as established from the histopathological study of the primary tumor and its metastases than on the age of the patient.

As we have already mentioned above, there is a certain relationship as to the interval between the appearance of the primary tumor and that of bone metastases, for the various groups. Such parallelism, namely, the longer that interval the longer the survival, exists in an analysis by stage of disease as well.

One may wonder to what extent the use of roentgen therapy may have contributed to lengthening the period of survival as well as to producing subjective or objective improvement. That could be established only by comparing a series of unirradiated cases. We do not have a comparable series of unirradiated cases. Nevertheless, let us assume that the efficiency of roentgen therapy may be expressed in terms of survival. Then Table VIII clearly demonstrates that the longer the survival, the better the results. Therefore we feel that we should be entitled to conclude that the use of roentgen irradiation in skeletal metastases is beneficial to the patient and may prolong life. However, Geschickter and Copeland[6] showed that the use of roentgen therapy was responsible for an increase of survival rang ng from 6.5 to 22 months, depending upon the form of treatment applied to the primary tumor.

PATHOLOGICAL FRACTURES

Pathological fractures of vertebrae, ribs, femur and humerus were observed. According to Copeland, the rate of incidence of such fractures is 15.0 per cent, the femur being involved in 13.0 per cent of the cases. Lenz and Freid found a rate of incidence of 26.0 per cent, with predominance in femur and humerus. In our series, pathological fractures were discovered in 11 cases, or 45.8 per cent. Vertebral collapse stands well at the top of the list with 7 cases. Many of the vertebral and rib fractures seemed to have consolidated following moderate doses of roentgen therapy, i.e. about 1,500 r. We believe that conservative dosage is indicated in order not to impair in any way bone consolidation. The usual orthopedic supports must be used in conjunction with roentgen irradiation.

We have endeavored in this study to discuss skeletal metastases from cancer of the breast from every angle without losing sight of the disease as a whole. Every possible factor which we thought might improve diagnosis or establish prognosis and direct treatment has been judiciously analyzed

and weighed. Finally, all the information which could be obtained from this collection of data and used as a directive has been linked in a logical sequence in the form of conclusions.

CONCLUSIONS

1. In this series of 24 cases of cancer of the breast with unquestionable skeletal metastases, 87.5 per cent belong to the clinical Groups II and III. Skeletal metastases very seldom occur unless there has been invasion of the axillary glands and the corresponding lymphatics.

2. As skeletal lesions were the first metastases to be found and the only ones demonstrable in 62.5 per cent of our cases, these must be looked for systematically as well as pulmonary metastases before any operation on the primary tumor. Examination for that purpose must be carried out clinically as well as roentgenographically. Subsequently, as the patient reports for regular follow-up examination, repeated search for metastases to bone must be made, particularly if the patient is complaining of so-called "neuralgic" or "rheumatic" pains. In view of the rate of incidence of metastatic lesions in certain bones, the roentgen examination of thoracic cage, lumbosacral spine and pelvis, including the upper femora, is especially indicated for investigation purposes.

3. The effect of possible dissemination of metastases by vigorous or careless handling of malignant tumors, their recurrences or metastases, especially during clinical examination or operative procedures, has not been discussed. However, we wish here to introduce a warning against such occurrences.

4. The age factor does not seem to be of any significant importance in relation to the incidence or degree of malignancy of metastases to bone in general. The rate of incidence of such metastases increases or decreases as the usual rate of incidence of primary cancer of the breast in the various decades.

5. The mean interval between the appearance of the primary tumor and that of the skeletal metastases in our series was thirty-four months, i.e. about three years, except for the age group twenty to thirty where that interval is but one-half as long. It is important to consider that the longer that interval, the longer the probable survival period.

6. At least 75 per cent of the bone lesions have an osteolytic character when first discovered. An osteoblastic lesion probably indicates a long standing or slowly growing skeletal lesion. In our series, a change from the osteolytic to the osteoblastic type, which we interpret as the result of depression or death of the neoplasm and repair by the remaining bone, has been induced by irradiation.

7. The prognosis in skeletal metastases from cancer of the breast is not quite as poor as it might seem. The average survival for the whole group of patients is 13.6 months, the maximum thirty-three months. As long as the skeletal metastases remain the only demonstrable lesion, the immediate prognosis is relatively good, but the development of other metastases, particularly in the lung or pleura, definitely shorten the survival period.

8. Under roentgen therapy, 66.0 per cent of the cases have subjective improvement; 26.0 per cent show also objective response to irradiation, the average survival period for that latter category increasing to eighteen months, the maximum being twenty-nine months.

9. Patients belonging to Group III should not be operated upon. Both the primary and secondary or metastatic lesions should be treated with irradiation only.

10. Finally, no case is so hopeless as to warrant discard without a trial of therapeutic roentgen irradiation. Results are oftentimes astonishingly good, even though they may not be permanent.

REFERENCES

1. Adair, F. E. Treatment of metastatic and inoperable mammary cancer. *Am. J. Roentgenol. & Rad. Therapy*, 1932, 27, 517-531.

2. Carnett, J. B., and Howell, J. C. Bone metastases in cancer of the breast. *Ann. Surg.*, 1930, *91*, 811–832.
3. Clarkson, W., and Baker, A. Five year cure of mammary carcinoma with multiple metastases to bone. Am. J. Roentgenol. & Rad. Therapy, 1936, *36*, 615–621.
4. Copeland, M. M. Bone metastases. *Radiology*, 1931, *16*, 198–210.
5. Ewing, James. Neoplastic Diseases. Fourth edition. W. B. Saunders Co., Philadelphia, 1941.
6. Geschickter, C. F., and Copeland, M. M. Tumors of Bone. American Journal of Cancer, 1931, p. 476.
7. Geschickter, C. F., and Copeland, M. M. Tumors of Bone. Revised edition. American Journal of Cancer, 1936, pp. 489–511.
8. Handley, W. S. Cancer of the Breast and Its Treatment. Second edition. Paul B. Hoeber, New York, 1922.
9. Lenz, M., and Freid, J. R. Metastases to the skeleton, brain and spinal cord from cancer of the breast and effect of radiotherapy. *Ann. Surg.*, 1931, *93*, 278–293.
10. Portmann, U. V. Classification of mammary carcinomas to indicate preferable therapeutic procedures. *Radiology*, 1937, *29*, 391–402.
11. Wulff, H. B. Radiological treatment of skeletal metastases in mammary cancer. *Acta radiol.*, 1939, *20*, 40–68.

TREATMENT OF HEMANGIOMAS WITH ROENTGEN RAYS*

By JAMES V. PROUTY, M.D.
CEDAR RAPIDS, IOWA

THE treatment of hemangiomas by roentgen rays is not new. In 1897 Jutassy found that their destructive effect upon the radiosensitive intima of the blood vessels faded and flattened the lesions.[12] Although the action of roentgen rays and rays from radium on individual cells are probably identical, radium has been used almost universally in the treatment of hemangiomas. Roentgen rays have not been utilized because of technical difficulties, such as the danger of electric shock, and the danger of overexposure due to inexact measurement of dosage. Since practically all therapy equipment is now shock-proof, and since sensitive and accurate measuring instruments are available, former objections to roentgen therapy no longer apply.

About five years ago we began to use unfiltered roentgen rays for the treatment of vascular nevi with good results. We now use only two techniques. In the first, we use unfiltered rays produced at 135 kv., and 18 cm. anode-skin distance. This technique is used for the treatment of all lesions thicker than 0.5 cm. and smaller than 3 cm. in diameter. About 30 per cent of the skin dose is absorbed by the first centimeter of tissue. In the second technique, we use unfiltered rays produced at 80 kv., and 15 cm. distance. This technique is used for the treatment of all flat lesions and of thick lesions whose diameter is greater than 3 cm. About 53 per cent is absorbed in the first centimeter.

The distribution of the rays produced by the two techniques, and the variations in skin dose with various sizes of field are shown in Tables I and II, respectively. The measurements upon which the tables are based were made with a small (4 by 4 by 4 mm.) ionization chamber in a small (10 by 10 by 10 cm.) water phantom. Our depth dose percentages are somewhat higher than those recently published by Braestrup.[5]

Hemangiomas are the most common neoplasm in infancy,[15,16] usually appearing within the first two or three weeks of life. Their cause is unknown. Lister[10] reports that 76 of 77 strawberry nevi, if untreated, disappear in the first five years of life. He believes growth is necessary during the first year to obtain a spontaneous cure. Growth did not occur in the lesion that failed to disappear. Many believe that spontaneous cure is relatively uncommon.

Clinically we divide hemangiomas of the skin into five types:

1. *Hemangioma simplex.* This is a blotchy area that occurs on the back of the neck in a high percentage of newborn infants. These blotchy areas usually disappear without treatment after several months or a few years.

2. *Capillary hemangioma.* We divide this type into two different kinds of lesions, the bright red, non-elevated nevus from which the color can be easily pressed out, and the dark red or purplish lesion from which it is difficult to press out the color. The first type of lesion usually responds to treatment. The second type, often called nevus flammeus or port wine stain, responds poorly to any kind of therapy. This lesion should probably not be treated by irradiation unless treatment can be given within the first month of life.

3. *Hypertrophic hemangioma, or "strawberry birthmark."* This is characterized by an elevated, slightly irregular, bright red lesion which usually grows faster than the infant. It responds well to irradiation because there is marked overgrowth of the sensitive endothelial cells. These lesions

* Presented at the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, Chicago, Ill., Sept. 24–29, 1944.

TABLE I

Size of field in cm.	1×1	2×2	3×3	4×4	5×5	7.5×7.5
Dosage (in air)	100 r	100 r	100 r	100 r	100 r	100 r
Dosage on skin	102 r	104 r	109 r	115 r	116 r	119 r
0.5 cm.	92	100	101	103	107	110
1.0 cm.	74	78	82	84	88	89
2.0 cm.	47	52	59	63	64	66
3.0 cm.	34	37	40	45	47	51
4.0 cm.	26	29	31	34	37	40
5.0 cm.	20	23	25	28	30	32

Surface and depth doses in roentgens per 100 r in air.
(135 kv.; 5 ma.; 18 cm. anode-skin distance; filter, none; half-value layer 1.1 mm. Al; intensity, 300 r per minute in air.)

may be mixed with the cavernous type, forming large, protruding masses, or with lymphoid and fibrous tissue.

4. *Cavernous hemangioma.* This type has large blood spaces which involve the skin and deeper structures or may be confined only to the tissues beneath the skin. A soft, bulging mass is present which often has a reddish or bluish color. The lesion can sometimes be made to disappear when continuous pressure is applied for a few minutes. These lesions are sometimes associated with hyperplasia of fatty or fibrous tissues, because after irradiation the color disappears but there is only partial disappearance of the bulging mass.

TABLE II

Size of field in cm.	1×1	2×2	3×3	4×4	5×5	7.5×7.5
Dosage in air	100 r	100 r	100 r	100 r	100 r	100 r
Dosage on skin	101 r	103 r	105 r	106 r	108 r	110 r
0.5 cm.	60	65	69	73	75	78
1.0 cm.	43	46	50	54	56	58
2.0 cm.	23	27	29	31	32	34
3.0 cm.	13	16	18	20	21	22
4.0 cm.	9	11	13	14	15	16
5.0 cm.	6	8	9	10	11	12

Surface and depth doses in roentgens per 100 r in air.
(80 kv.; 10 ma.; 15 cm. anode-skin distance; filter, none; half-value layer 0.57 mm. Al; intensity, 267 r per minute in air.)

FIG. 1. R. B., aged eight weeks. *A*, elevated, ulcerated, hypertrophic hemangioma on neck and shoulder. Diameter 6 cm. *B*, eleven months later, after two roentgen treatments to entire area and four roentgen treatments to smaller areas. Total dose 2,600 r.

5. *Spider nevi.* This lesion consists of a network of small, dilated vessels arising from one or more central vessels. Pressure by a small magnifying glass usually identifies the feeders. They are best destroyed by inserting a fine cambric needle into the central vessels and then touching the needle with a coagulating current until a slight bleaching occurs around the needle. This is done without local anesthesia and may have to be repeated two or three times before the lesion is entirely destroyed. The procedure is painful.

Irradiation of hemangiomas by roentgen or radium rays produces a gradual shrinking and obstruction of the vascular spaces. The degree of sensitivity depends upon the type of endothelial cells, the character of the surrounding stroma, and the size of the vascular spaces. We have found that, if treatment is started soon after the appearance of the hemangioma, while it is more sensitive, less irradiation is necessary and better cosmetic results are obtained. According to Ward and Covington,[11] and others,[2,8,11] the radiosensitivity of hemangiomas decreases in direct proportion to the age of the infant. Children older than three or four years should be treated very cautiously because of the danger of overdosage. Many of our cases treated within the first two or three months of life required only one or two treatments. If the lesion is allowed to grow without treatment, it may reach considerable size, become ulcerated and infected. When this occurs any type of treatment results in considerable scarring.

We have found roentgen irradiation to be much more satisfactory than other methods of treatment which we have used. We can treat the lesions with roentgen rays more homogeneously and get a more even disappearance of the color and tumor mass. This is especially true when the lesions are of such size that the radium applicator has to be applied to more than one area. Much larger areas can be treated with roentgen

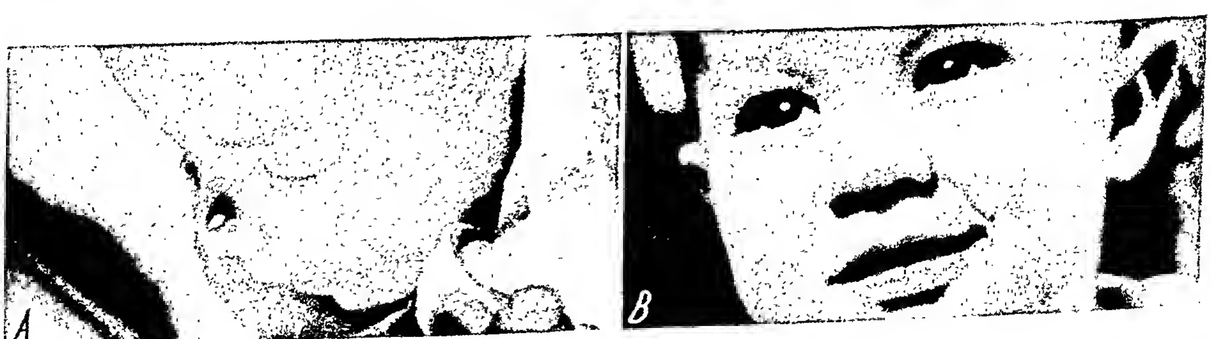

FIG. 2. W. F., aged seven weeks. *A*, elevated, bluish-red, cavernous hemangioma on nose. *B*, nine months later, after three roentgen treatments. Total dose 1,300 r.

Fig. 3. J. T., aged six months. *A*, elevated, hypertrophic hemangioma on left forearm. Diameter 3 cm. *B*, eight months later, after three roentgen treatments. Total dose 1,400 r.

rays at one time than with radium. The treatments are very short, lasting from one to three minutes, depending upon the technique used. The infant can be held or strapped in position for the treatments. Perhaps the greatest advantage of roentgen rays is their availability. In Iowa roentgen therapy is available in many more places than radium. We believe this also applies to a large part of the United States. Another advantage is the ease and the cheapness of treatment. The average cost is from three-fourths to one-half less than radium. We have had no experience in treating hemangiomas with the contact roentgen therapy method. From reports in the literature excellent results are obtained.[1,6,8,9]

Our method of treating hemangiomas consists of cutting an opening in lead foil the size and shape of the lesion. Occasionally the opening is made slightly larger in order to include subcutaneous vessels and the growing edge of the lesion. From 300 to 600 r is given at one treatment, depending

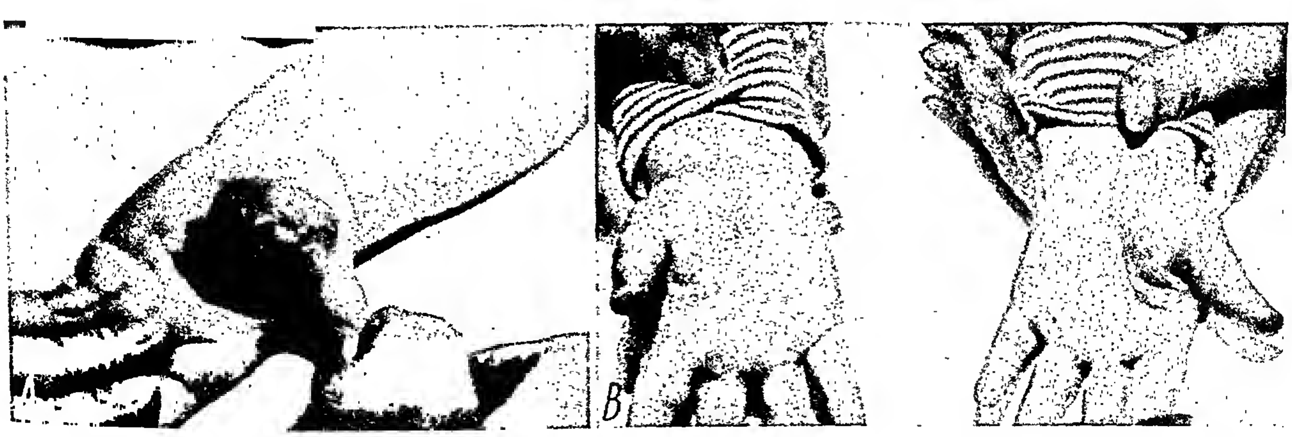

Fig. 4. N. C., aged ten and one-half months. *A*, bluish-red, cavernous hemangioma on palm of left hand. Diameter 3 cm. *B*, eight months later, after five roentgen treatments. Total dose 2,500 r.

upon the size and location of the lesion. If the hemangioma is 1 cm. or less in diameter, and there is no danger of injury to the subcutaneous structures, 600 r is given. When the lesion is 5 cm. or more in diameter, from 300 to 400 r is used. We have had very few noticeable skin reactions with these doses. An occasional mild erythema occurs at the edge of the lesion when the larger dose is used. The patients are seen in one month, and if there has been no response to the treatment and if no erythema is present, they are treated again. When the lesions are fading and flattening, we wait at least one or two months more before continuing treatment. If the infant is less than two or three months of age, it is surprising how often only one or two treatments are needed to produce an excellent result. I am convinced that if all hemangiomas were treated as soon as discovered there would be very little scarring or ulceration. In some of the large hemangiomas loss of color is more rapid in the center. When this occurs, lead is cut out and placed in the central area for part or all of the succeeding treatments.

Unfortunately, the treatment of vascular nevi is not without danger,[3,4,7,13] as there are various complications and residuals. Great care should be taken in the treatment of lesions near epiphyses and glandular structures. As little as 400 r delivered to the epiphyseal plate will produce a delay of bone growth. It is usually better to treat hemangiomas in the region of the testes by some other method than irradiation. Overdosage in any area will produce blistering, possibly ulceration, and infection with increased scarring. Large total doses may result in growth disturbance, in telangiectasia, or in skin atrophy. Loss of hair should be considered, although we have had very little permanent loss of hair in treating lesions of the scalp early in infancy. It is not uncommon to find that the hair comes in a darker shade after epilation.

From December, 1939, to January, 1944, we treated with unfiltered roentgen rays 129 cases of hemangiomas in infancy and childhood with better cosmetic results than we were able to obtain with radium or any other method. We have classified our results into four groups:

Those with a minimum of scarring or with complete disappearance of color and tumor mass were considered excellent. These lesions are not noticeable at the usual conversation distance. This result was obtained in 87 of the 129 cases.

Good results were obtained in 27 cases. These had either a more noticeable scar or a few residual vessels but there was complete disappearance of the tumor mass.

Fair results were obtained in 8 cases. These consisted of a residual tumor mass, some color and scarring.

Poor results were obtained in 4 cases. One of these was a pigmented hemangioma which showed no response to treatment. The second was a nevus flammeus. The third was a large, mixed lymphangioma involving the right scalp, face and neck, and probably complicated by intracranial hemangiomas. The fourth poor result was probably due to overtreatment of the inner half of the proximal tibial epiphysis as there is delayed growth of the inner half of the tibia producing a slight genu varum. This patient received two treatments of 450 r each, with an interval of one month. We have since used tangential irradiation with good results in lesions near the epiphyseal plate and without apparent epiphyseal injury. We recently observed some of the earlier cases and many of the areas treated have improved in appearance over a period of four or five years. Two cases involving the entire upper eyelids were treated with excellent results. A lead shield was placed in the conjunctival space to protect the eye.

The hemangiomas seem to respond more rapidly to roentgen irradiation than to treatment with radium, possibly because they are now treated at a much earlier age. We have not had the skin reactions with roentgen irradiation that were occasionally observed when we used radium. These reactions were, perhaps, due to improper construction of the radium applicators so that

uneven distribution of radiation was obtained.

CONCLUSIONS

In our experience unfiltered roentgen irradiation, using 80 to 135 kv., has proved superior to other methods of treating hemangiomas of the skin because the lesions can be treated more homogeneously, more rapidly, more economically, and because larger areas can be treated at one time. We believe equally good results can be obtained wherever roentgen therapy is available.

I wish to express my appreciation to Dr. A. W. Erskine for his help and advice in the establishment of the techniques and in the preparation of the depth dosage table.

REFERENCES

1. ApThomas, I. Contact x-ray treatment of cavernous angioma in children. *Brit. J. Radiol.*, 1942, *15*, 43–46.
2. Bailey, W., and Kiskadden, W. S. Treatment of hemangiomata, with special reference to unsatisfactory results. *Radiology*, 1942, *38*, 552–561.
3. Barr, J. S., Lingley, J. R., and Gall, E. A. Effect of roentgen irradiation on epiphyseal growth; experimental studies on albino rat. Am. J. Roentgenol. & Rad. Therapy, 1943, *49*, 104–115.
4. Bisgard, J. D., and Hunt, H. B. Influence of roentgen rays and radium on epiphyseal growth of long bones. *Radiology*, 1936, *26*, 56–64.
5. Braestrup, C. B. Depth dose measurements for 100-, 120-, and 135-kv. roentgen rays. *Radiology*, 1944, *42*, 258–272.
6. Goin, L. S. Low-voltage contact irradiation therapy; further experience. *Radiology*, 1944, *42*, 241–245.
7. Hinkel, C. L. Effect of roentgen rays upon the growing long bones of albino rats; quantitative studies of growth limitation following irradiation. Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 439–457.
8. Hodges, F. M., Snead, L. O., and Berger, R. A. Roentgen therapy of hemangiomata. *Radiology*, 1941, *36*, 700–704.
9. Kerr, H. D. Irradiation treatment of cavernous hemangioma with special reference to so-called contact roentgen irradiation. *Radiology*, 1942, *39*, 383–388.
10. Lister, W. A. Natural history of strawberry naevi. *Lancet*, 1938, *1*, 1429–1434.
11. Molesworth, E. H. Importance of early treatment of vascular naevi. *Med. J. Australia*, 1933, *2*, 217.
12. Pusey, W. A., and Caldwell, E. W. The Practical Application of the Röntgen Rays in Therapeutics and Diagnosis. W. B. Saunders & Co., Philadelphia, 1903, p. 565.
13. Regan, E. M., and Wilkins, W. E. Effect of large doses of x-rays on growth of young bone. *J. Bone & Joint Surg.*, 1936, *18*, 61–68.
14. Ward, G. E., and Covington, E. E. Hemangiomas of skin. *J. Am. M. Ass.*, 1940, *114*, 2069–2075.
15. Watson, W. L., and McCarthy, W. D. Blood and lymph vessel tumors; report of 1,056 cases. *Surg., Gynec. & Obst.*, 1940, *71*, 569–588.
16. Winer, L. H. Hemangiomas; classification and treatment. *Journal-Lancet*, 1941, *61*, 168–172.

DISCUSSION

Dr. Rollin H. Stevens, Detroit, Mich. I should be inclined to question the advisability of Dr. Prouty's second technique—use of the unfiltered rays at 80 kv. at 15 cm. distance for all flat lesions whose diameter is greater than 3 cm., about 47 per cent being absorbed in the first centimeter. It would seem to me it would be better to reserve that treatment for the smaller lesions and use the first technique he mentioned for the larger ones. I am a little afraid of too much irradiation reaction in those cases.

He claims that the advantages over radium are that there are more of the roentgen rays that are homogeneous, the treatment is shorter and less expensive. If the treatment is so applied that it covers the entire nevus, including the border and a millimeter or two beyond, the results of the treatment should be as homogeneous with radium as with roentgen radiation.

One difficulty in applying radium is to get the radium skin distance exactly the same in all parts of the lesion. As has been pointed out by Strandqvist, an increase of 2 mm. in the distance reduces the intensity to 40 per c nt. That is quite a substantial reduction and may account for lack of homogeneity in scme of the cases treated by radium because of variation in distance from radium to skin.

When moulded compounds are used as applicators it is almost impossible to keep the distance of the radium needle used in the applicator within the limits of 2 mm. Hence, homogeneity of action is lost,—and Strandqvist has developed applicators of glass with channels in the center to receive the radium needle. They are exactly 5 mm. in diameter. If any number of these are placed side by side, the distance from the axis of one needle to the other

and to the skin is also exactly 5 mm., these applicators being placed directly on the skin.

We used these glass capsules for some time after reading Strandqvist's paper in 1939, but in the last two years we have had some applicators made of lucite for single needles and rows of two, three and four in one applicator. We have platinum coverings over our needles to make a 0.5 mm. platinum filter. Up to the present we have used only gamma rays since we have been using these applicators.

Formulae for working out the dose based on Sievert's tables are provided. From these we have had Dr. Gratzek, formerly on our staff, prepare a dosage chart. We cover the lesion with one or two rows of capsules, select the number of roentgens we think a case may require, consult our chart and get the time factor required. Strandqvist uses 8 or 10 mg. needles in the capsules. We generally use 5 mg. needles because we have more of them than of the 10 mg. Of course they require twice the time, worked out by Strandqvist's charts. In this way we are able to give fairly accurate homogeneous doses of radium.

We have no doubt just as good results may be accomplished with roentgen irradiation and with less trouble, except I do not feel we can easily keep a child still under that treatment long enough to get an exactly limited and homogeneous irradiation.

We use doses of 500 to 800 r, depending on the age of the child, the depth of the lesion, its proximity to the epiphyses, and other important structures.

Dr. U. V. Portmann, Cleveland, Ohio. At the 1940 meeting of the Radiological Society of North America I discussed a paper on roentgen therapy of hemangiomas given by Drs. Fred M. Hodges and Raymond A. Berger of Richmond, Virginia. I showed photographs of the results of treatment of a very large cavernous hemangioma involving the whole forearm and most of the hand of a child. This was treated with radium, and the "spottiness" that remained was given contact roentgen therapy with satisfactory results as shown by these photographs.

I warned the parents when treatment was started that the affected forearm might be shorter. This occurred, as shown by the photograph and roentgenogram of both forearms taken three years later. There is evidence of delay in development of ossification centers of the metacarpals, the radius, and the ulna. Although the forearm is shortened, there is no apparent interference with function.

Another case may be of interest. The photograph shows a cavernous hemangioma involving the entire left side of the face including the eyelids. The child also had a large hemangioma on the back of the neck, harelip, and cleft palate. I hesitated to treat this baby but finally did so on the insistence of the parents. Only contact roentgen therapy was given to the face. The physical factors were 50 kv., 2 ma., 2.1 cm. focus-skin distance, filter 1.0 mm. Al. Usually several areas were given 200 to 300 r each at monthly intervals. The hemangioma on the back of the neck was given the same dosage with 200 kv. and filter equivalent to half-value layer of 0.9 mm. Cu. The next photograph shows the remarkable improvement that has taken place in the past year and one-half. Treatment will be continued.

Dr. Prouty (closing). In reply to a question regarding telangiectasis, we had 1 or 2 cases early in the series when we were using larger doses more frequently. We did not use compression in the treatment of any of these lesions.

In reply to Dr. Stevens' question as to why we use 80 kv. in the treatment of superficial and large lesions it is because we do not want a large depth dose. In infants the distance from the skin surface to vital structure is very little, especially the bony structures near the epiphyses.

What I mean by a flat lesion is one with not more than 1 or 2 mm. elevation. If 135 kv. is used near the epiphyses, the depth dose percentage at 1 and 2 cm. is too great and there is danger of injury, resulting in a disturbance of bone growth.

TUMORS IN ONE OF HOMOLOGOUS TWINS

HODGKIN'S DISEASE WITH PRIMARY SKELETAL MANIFESTATIONS*

By HERMAN CHARACHE, M.D.
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IN THE July, 1941, issue of this JOURNAL a report of tumors in one of homologous twins was made.[1] It was emphasized that "Were sufficient clinical material available, the study of homologous twins would seemingly contribute a great deal toward solving the genetic theory of cancer." In this report 2 cases of Hodgkin's disease were included. Two additional cases have since been found in the literature (Smith,[7] Macklin[4]). The latter case was mentioned in an excellent report on "Tumors in monozygotic and dizygotic twins" before the Seventh International Congress of Genetics at Edinburgh, Scotland, in 1939.

The case to be reported here is the fifth case of Hodgkin's disease in one of homologous twins. In addition, it presents very interesting findings; namely, skeletal involvement as shown by roentgenographic studies without any other clinical manifestation of Hodgkin's disease. The diagnosis was established by autopsy findings. Other cases of primary skeletal manifestation of Hodgkin's disease without clinical findings of the disease were reported by Priesel and Winkelbauer,[5] Krumbhaar,[2] Livingston,[3] and Schenck.[6]

CASE REPORT

P.T., a white female, aged five, one of homologous twins, was admitted to the Brooklyn Cancer Institute on January 6, 1940, with a history of pain in the right hip and right shoulder, fever, and loss of weight of ten weeks' duration.

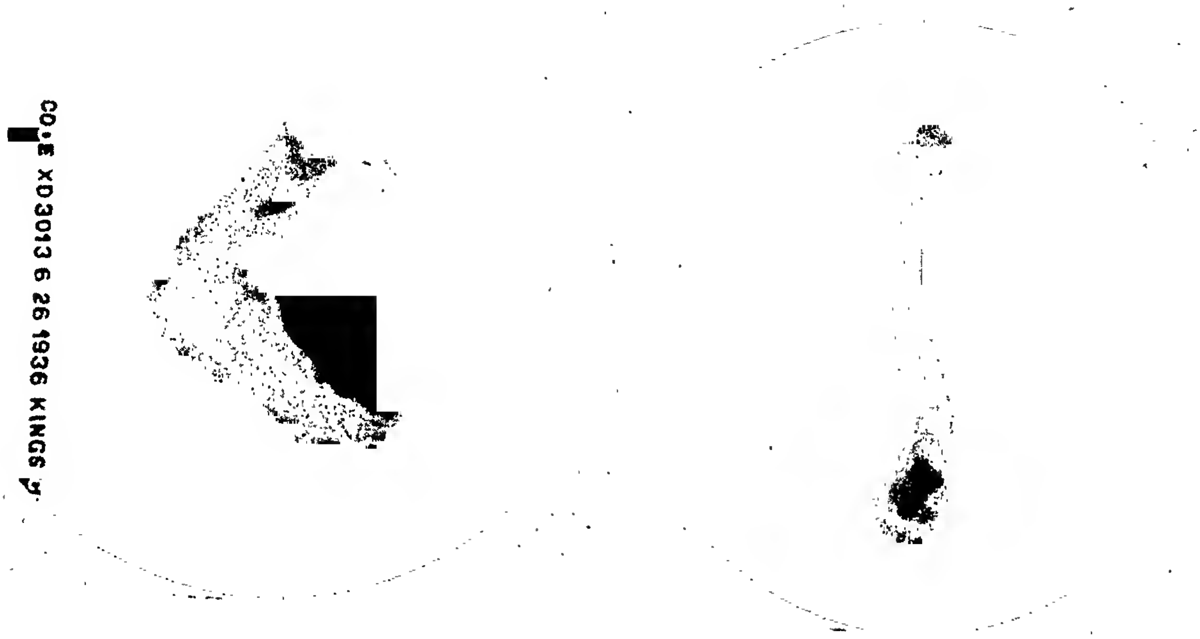
Ten weeks previous to admission to the Brooklyn Cancer Institute, the patient developed pain in the right hip and had difficulty in walking. Shortly afterward she began to have pain in the region of the right clavicle. She became irritable, cried a great deal, lost her appetite, and began to lose weight. When the mother noticed that the child had developed a fever, she took her to a hospital, where a diagnosis of rheumatic fever was made. However, when roentgenograms revealed a partial de-

Fig. 1. Hodgkin's disease in one of homologous twins. (Healthy twin refused to take off shoes.)

struction of the right ilium and right clavicle, she was transferred to our Institute for diagnosis and treatment.

The patient was born on May 23, 1934, full term, normal vertex delivery. A few minutes later her twin sister was born. Each weighed $3\frac{1}{2}$ pounds. Both were kept in an incubator for a

* From the Brooklyn Cancer Institute, Brooklyn, N. Y.



A *B*

Fig. 2. Postmortem roentgenogram showing destruction of distal end of ilium (*A*) and clavicle (*B*) by Hodgkin's disease.

Fig. 3. Hodgkin's disease of skull.

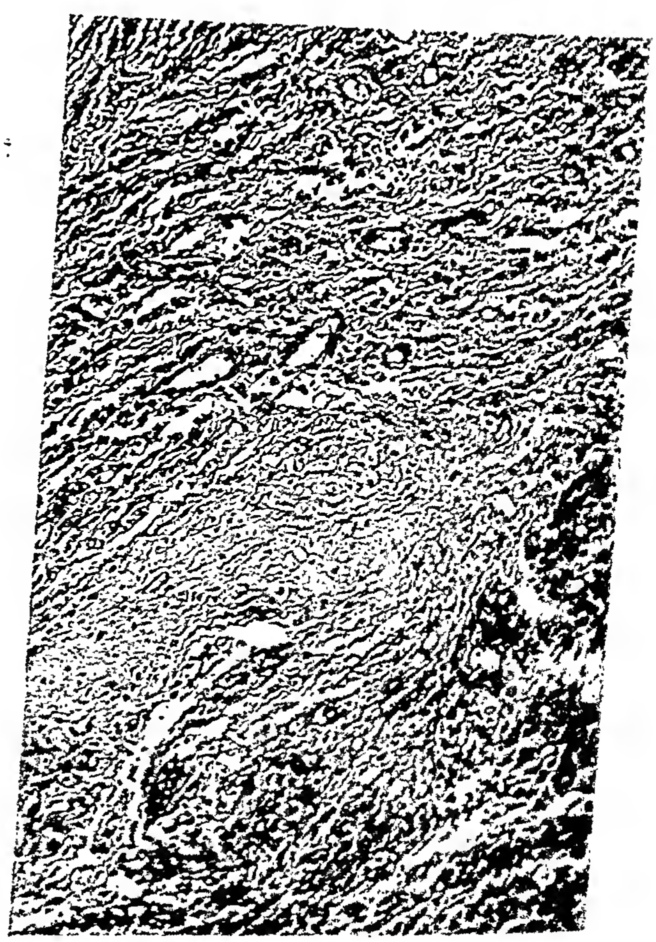


Fig. 4. Photomicrograph (140×) showing Hodgkin's disease of the ilium.

long time. When the milk formula did not agree with one, it did not agree with the other. When they grew older, both had the same likes and dislikes regarding food. Both had the same bowel and urinary habits. Both children had measles at about the same time. When the patient developed whooping cough, her twin sister was taken to her grandmother's; however, she too developed whooping cough.

The parents are in good health. Their blood Wassermann reactions were negative, and there is no history of cancer in the family.

Physical examination revealed a pale, undernourished five year old child, acutely and chronically ill. Her temperature varied from 98° to 103° F., pulse 90 to 135, and respiration 22 to 44. A few discrete pea-sized glands were found in the neck and inguinal regions. The heart and lungs showed no clinical evidence of a pathologic condition. The abdomen was somewhat distended; no masses were palpable. The liver and spleen were not palpable.

Urinalysis and the blood Wassermann reaction were negative. The blood count showed 3,820,000 red blood cells, with 72 per cent hemoglobin. The leukocyte count was 28,500, with 91 per cent polymorphonuclear leukocytes and 9 per cent lymphocytes. The blood chemistry revealed urea 7.6 mg., sugar 83 mg., calcium 11 mg., phosphorus 3.7 mg., phosphatase 13 units, cholesterol 185.1 mg., cholesterol ester 65.3 mg.

The entire skeleton was roentgenographed except the feet. The positive roentgen findings were as follows: Two cherrystone sized areas of rarefaction in the parietal region of the skull, rarefaction of outer half of right clavicle, and a round area of rarefaction measuring $1\frac{1}{2}$ inches of the right ilium. Roentgen examination of the chest showed hypertrophy of the left ventricle; otherwise there was no sign of a pathologic condition. The intravenous pyelogram suggested a bulging of the outer surface of the right kidney.

The patient remained in the hospital for a month under supportive treatment. She received palliative roentgen therapy to the right hip and clavicle. Her general condition grew progressively worse, and she became moribund. On the morning of February 6 she was suddenly seized with severe air hunger. An emergency portable roentgen examination revealed the collapse of both lungs. She died shortly afterward.

An autopsy was performed by Dr. Herman Bolker. The anatomico-pathologic diagnosis was as follows: Reticulo-endothelial sarcoma (atypical Hodgkin's disease) of the thymus, cervical lymph nodes, and lungs, with secondary emphysema and bilateral pneumothorax, liver, spleen and bones. The sections were submitted to several pathologists, including Dr. James Ewing, who confirmed the diagnosis of Hodgkin's disease.

The patient's homologous twin is being observed at three-month intervals. Physical examination, including roentgenographic study of her skeleton and lungs, shows no evidence of any pathologic condition. She was last seen on August 24, 1944, four years and eight months after the onset of symptoms in the deceased homologous twin.

REFERENCES

1. Charache, H. Tumors in one of homologous twins; Hodgkin's disease; osteogenic sarcoma. Am. J. Roentgenol. & Rad. Therapy, 1941, *46*, 69–74.
2. Krumbhaar, E. B. Hodgkin's disease of bone marrow and spleen without apparent involvement of lymph nodes. *Am. J. M. Sc.*, 1931, *182*, 764–769.
3. Livingston, S. K. Hodgkin's disease of skeleton without glandular involvement. *J. Bone & Joint Surg.*, 1935, *17*, 189–194.
4. Macklin, M. T. Analysis of tumors in monozygous and dizygous twins, with report of 15 unpublished cases. *J. Hered.*, 1940, *31*, 277–290.
5. Priesel, A., and Winkelbauer, A. Placentare Uebertragung des Lymphogranuloms. *Virchow's Arch. f. path. Anat.*, 1926, *262*, 749–765.
6. Schenck, S. G. Hodgkin's disease with bone manifestations. *New York State J. Med.*, 1937, *37*, 27–37.
7. Smith, C. A. Hodgkin's disease in childhood; clinical study with résumé of literature to date. *J. Pediat.*, 1934, *4*, 12–38.

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Forty-fifth Annual Meeting: 1945, canceled.

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Representatives on American Board of Radiology: Douglas Quick, New York, N. Y., B. P. Widmann, Philadelphia, Pa., F. W. O'Brien, Boston, Mass.

Twenty-eighth Annual Meeting: 1945, canceled.

EDITORIAL

AMPUTATIONS

AMPUTATION surgery has always assumed increasing importance in wartime because of the relatively common need for the removal of extremities destroyed directly by the missiles of war or indirectly through loss of blood supply, gas gangrene and other severe infections. The recent advances made in surgery, chemotherapy and supportive measures have largely overcome the dangers of infection, so that amputation is seldom indicated for infection alone. In military surgery, emergency amputations are performed under conditions which are often unfavorable, delay is frequently encountered and early evacuation must be observed. Under these circumstances all emergency amputations for severe trauma, infection or gangrene must be of the open type commonly known as a guillotine amputation. The indications for emergency amputation as well as for subsequent reconstructive surgery depend in many instances on careful roentgenological technique and interpretation. If properly done, such an amputation permits early closure of the stump by continuous skin traction. In selected cases, early secondary suture may be successful, but this should not be attempted unless these patients remain under observation. Secondary revision of the stump is required in most cases before a prosthesis is fitted. These various factors have all been taken into consideration in the establishment of the current policy for amputations in the United States Army.

Approximately 5 per cent of the major amputation cases have lost part of two extremities, less than one per thousand has lost part of three, and recently one quadruple case has occurred in Army combat casualties in this war. Fortunately, the more disabling amputations are less common, disability increasing in the following order: below the knee, above the knee, below the elbow and above the elbow.

Sites considered optimum for amputation are based upon experience and depend on the types of the prostheses available. While the general principles of amputation surgery are essentially the same throughout, there will continue to be a gradual evolution as new prosthetic devices are produced. This is particularly true with amputations near the major joints, including the ankle, knee, wrist and elbow. Standardization and improvement of prostheses have become a matter of national interest and importance with the result that civilian and military agencies have undertaken coordinated research and development. This effort is already bearing fruit and will achieve greater success in the near future.

The goal in amputation surgery is the restoration of function and not merely the amputation itself. This program requires the coordinated effort of all interested personnel including the surgeon, limb fitter, physical therapist, occupational therapist and those engaged in education, recreation and vocational rehabilitation. Finally, industry must employ and train the amputees to take their place among other employees. As a profession and as a nation, we are faced with a special challenge to enable the physically handicapped, of which the amputees constitute a large portion, to assume their place and responsibility in the world along with their fellow men. Experience has now shown that such a program is industrially safe and economically sound. Therefore, special care should be taken in surgical reconstruction, prosthetic fitting and training in order that we may achieve the maximum social and economic rehabilitation of the war amputee.

Norman T. Kirk, Major General,
United States Army,
The Surgeon General

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. H. Dabney Kerr, University Hospital, Iowa City, Iowa. Annual meeting: 1945, canceled.

American College of Radiology
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago.

Section on Radiology, American Medical Association
Secretary, Dr. U. V. Portmann, Cleveland Clinic, Cleveland, Ohio. Annual meeting: 1945, canceled.

Arkansas Radiological Society
Secretary, Dr. J. S. Wilson, Mack Wilson Hospital, Monticello, Ark. Meets every three months and also at time and place of State Medical Association.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: 1945, to be announced.

Radiological Section, Baltimore Medical Society
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

Section on Radiology, California Medical Association
Secretary, Dr. Gordon G. King, 3700 California St., San Francisco 18, Calif.

Radiological Section, Connecticut Medical Society
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets bi-monthly on second Thursday, at place selected by Secretary. Annual meeting in May.

Section on Radiology, Illinois State Medical Society
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

Radiological Section, Los Angeles County Medical Association
Secretary, Dr. Roy W. Johnson, 1407 S. Hope St., Los Angeles, Calif. Meets on second Wednesday of each month at the County Society Building.

Radiological Section, Southern Medical Association
Secretary, Dr. Roy G. Giles, Temple, Texas.

Brooklyn Roentgen Ray Society
Secretary, Dr. Leo Harrington, 880 Ocean Ave., Brooklyn, N.Y. Meets monthly on fourth Tuesday, October to April.

Buffalo Radiological Society
Secretary, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months.

Chicago Roentgen Society
Secretary, Dr. F. H. Squire, 1754 W. Congress St., Chicago 12, Ill. Meets second Thursday of each month October to April inclusive at the Palmer House.

Cincinnati Radiological Society
Secretary, Dr. Samuel Brown, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

Cleveland Radiological Society
Secretary, Dr. D. D. Brannan, 11311 Shaker Blvd., Cleveland 4, Ohio. Meets at 6:30 P.M. at Allerton Hotel on fourth Monday each month, October to April, inclusive.

Dallas-Fort Worth Roentgen Study Club
Secretary, Dr. X. R. Hyde, Medical Arts Bldg., Fort Worth, Texas. Meetings held in Dallas on odd months and in Fort Worth on even months, on third Monday, at 7:30 P.M.

Denver Radiological Club
Secretary, Dr. A. Page Jackson, Jr., 1612 Tremont Place, Denver, Colo. Meets third Friday of each month at Denver Athletic Club.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

Florida Radiological Society
Acting Secretary, Dr. Walter A. Weed, 204 Exchange Bldg., Orlando, Fla. Meetings in May and November.

Georgia Radiological Society
Secretary, Dr. James J. Clark, 478 Peachtree St., Atlanta, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

Radiological Society of Kansas City
Secretary, Dr. Arthur B. Smith, 800 Argyle Bldg., Kansas City, Mo. Meets third Thursday of each month.

Illinois Radiological Society
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meets three times a year.

Indiana Roentgen Society
Secretary, Dr. H. C. Ochsner, Methodist Hospital, Indianapolis. Meets annually second Sunday in May.

Iowa X-Ray Club
Secretary, Dr. Arthur W. Erskine, 326 Higley Bldg., Cedar Rapids, Iowa. Luncheon and business meeting during annual session of Iowa State Medical Society. Special meetings by announcement.

Kentucky Radiological Society
Secretary, Dr. W. C. Martin, 321 W. Broadway, Louisville. Meets annually in Louisville on first Saturday in Apr.

Long Island Radiological Society
Secretary, Dr. Marcus Wiener, 1430-48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:30 P.M.

Louisiana Radiological Society
Secretary, Dr. J. R. Anderson, 1130 Louisiana Ave., Shreveport. Meets annually during Louisiana State Medical Society Meeting.

Michigan Association of Roentgenologists
Secretary, Dr. E. M. Shebesta, 1429 David Whitney Bldg., Detroit. Three meetings a year, Fall, Winter, Spring.

Milwaukee Roentgen Ray Society
Secretary, Dr. C. A. H. Fortier, 231 W. Wisconsin Ave., Milwaukee, Wis. Meets monthly on second Monday at University Club.

Minnesota Radiological Society
Secretary, Dr. Annette T. Stenstrom, 1218 Medical Arts Bldg., Minneapolis, Minn. One meeting a year at time of Minnesota State Medical Association.

Nebraska Radiological Society
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month, at 6 P.M. at either Omaha or Lincoln.

New England Roentgen Ray Society
Secretary, Dr. George Levene, Massachusetts Memorial Hospitals, Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

New Hampshire Roentgen Ray Society
Secretary, Dr. Richard C. Batt, Berlin, N. H. Four meetings a year.

Radiological Society of New Jersey
Secretary, Dr. H. R. Brindle, 501 Grand Ave., Asbury Pa[illegible] Meets annually at time and place of State Medical So[illegible] ciety. Mid-year meetings at place chosen by president.

New York Roentgen Society
Secretary, Dr. Ramsay Spillman, 115 East 61st St., New York City. Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

North Carolina Roentgen Ray Society
Secretary, Dr. Major Fleming, Rocky Mount, N. C. [illegible]

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

nual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

North Dakota Radiological Society
Secretary, Dr. L. A. Nash, St. John's Hospital, Fargo. Meetings held by announcement.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

Ohio Radiological Society
Secretary, Dr. Henry Snow, 1061 Reibold Bldg., Dayton, Ohio. Meets during annual meeting of Ohio State Medical Association.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport.

Philadelphia Roentgen Ray Society
Secretary, Dr. C. L. Stewart, Jefferson Hospital, Meetings first Thursday of each month, October to May, at at 8:00 p.m., in Thomson Hall, College of Physicians, 21 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. L. M. J. Freedman, 4800 Friendship Ave. Meets 6:30 p.m. at The Ruskin on second Wednesday, each month, October to May inclusive.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Murray P. George, Strong Memorial Hospital. Meets monthly on third Monday from October to May, inclusive, 8 p.m. at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary Dr. A.M. Popma, 220 N. First St., Boise, Idaho.

St. Louis Society of Radiologists
Secretary, Dr. Edwin C. Ernst, Beaumont Medical Building, St. Louis, Mo. Meets fourth Wednesday of each month, except June, July, August, and September, at a place designated by the president.

San Diego Roentgen Society
Secretary, Dr. Henry L. Jaffe, Naval Hospital, Balboa Park, San Diego, Calif. Meets monthly on first Wednesday at dinner.

San Francisco Radiological Society
Secretary, Dr. Carlton L. Ould, University of California Hospital, San Francisco 22. Meets monthly on the third Thursday at 7:45 p.m., first six months of the year at Lane Hall, Stanford University Hospital, and second six months at Toland Hall, University of California Hospital.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 p.m., September to May inclusive.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, 707 Walnut St., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. Asa E. Seeds, Baylor Hospital, Dallas, Texas. Next annual meeting, Temple, Texas, Jan. 17, 1945.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 p.m. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 p.m., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. E. L. Flanagan, 116 E. Franklin St., Richmond, Va. Meets annually in October.

Washington State Radiological Society
Secretary, Dr. Thomas Carlile, 1115 Terry St., Seattle. Meets fourth Monday each month, October through May, College Club, Seattle.

X-ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly, third Thursday evening.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Medical Members' meeting held monthly on third Friday at 2:30 p.m. and Ordinary Meeting at same time on following Saturday, October to May, 32 Welbeck St., London, W.1.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month at 4:45 p.m. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. J. W. McKay, 1620 Cedar Ave., Montreal, P. Q.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

South America

Sociedad Argentina de Radiologia
Secretary, Dr. Guido Gotta, Buenos Aires, Argentina. Meetings are held monthly.

Sociedad Peruana de Radiologia
Secretary, Dr. Victor Giannoni, Apartado, 2306, Lima, Peru. Meetings held monthly except during January, February and March, at the Asociación Médica Peruana "Daniel A. Carrión, Villalta, 218, Lima.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse Biel. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad: USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 p.m.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

CLINICAL CANCER TEACHING DAY

A Clinical Cancer Teaching Day will be held at the Homer Folks Tuberculosis Hospital, Oneonta, New York, on Wednesday, October 3, 1945. The Clinical Program from 2 to 4 P.M. will consist of "Clinical Demonstration and Discussion of Cancer Patients" by Drs. Milner, Stewart, Treves and Twombly. Following this, two papers will be given: "Ovarian Carcinoma" by Gray H. Twombly, M.D., Memorial Hospital, New York: "Cancer of the Breast" by Norman Treves, M.D., Memorial Hospital, New York. Dinner will be served at the Homer Folks Tuberculosis Hospital at 6:15. The evening meeting will be called to order at 7:30 and the following program will be given: "Carcinoma of the Bladder" by William A. Milner, M.D., Albany Medical College, Albany, New York; "Biopsy in Tumors" by Fred W. Stewart, M.D., Memorial Hospital, New York.

Advance reservations are required for the dinner and should be sent to Dr. Ralph Horton, Superintendent, Homer Folks Tuberculosis Hospital, Oneonta, New York.

CANCER TEACHING DAY

A Cancer Teaching Day will be held at the Governor Clinton Hotel, Kingston, New York, on Wednesday, October 17, 1945. The program will begin at 3:30 P.M., and the following papers will be presented: "Cancer of the Skin and Allied Tumors" by Earl D. Osborne, M.D., University of Buffalo School of Medicine, Buffalo, New York; "The Role of the Practicing Physician in the Care of Cancer" by Frederick S. Wetherell, M.D., Syracuse University College of Medicine, Syracuse, New York. Dinner will be served at the Governor Clinton Hotel at 6:30. At the evening meeting beginning at 7:30 the following papers will be given: "Cancer of the Prostate" by Charles B. Huggins, M.D., University of Illinois, Chicago, Illinois; "Biopsy in Tumors" by Fred W. Stewart, M.D., Memorial Hospital, New York.

Reservations for the dinner must be made in advance and should be sent to Dr. Frederick H. Voss, 69 Spring St., Kingston, New York.

CANCER TEACHING DAY

A Cancer Teaching Day will be held at the Auditorium, Albany College of Pharmacy, Albany, New York, on Thursday, October 18, 1945. The meeting will be called to order at 3:30 P.M. and the following papers will be given: "Cancer of the Head and Neck" by Hayes Martin, M.D., Memorial Hospital, New York; "Cancer of the Prcstate" by Charles B. Huggins, M.D., University of Illinois, Chicago, Illinois. A buffet supper will be served at 6:30. The evening meeting will begin at 8:00 o'clock and the following papers will be presented: "Cancer of the Stomach" by George T. Pack, M.D., Memorial Hospital, New York; "Hormone Therapy and the Prevention of Gynecologic Malignancies" by Clyde L. Randall, M.D., University of Buffalo School of Medicine, Buffalo, New York.

Reservations for the buffet supper are required in advance and should be sent to Dr. Arthur F. Holding, 142 Washington Avenue, Albany 6, New York.

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, M.D., B.S., M.A., 103 Rutledge Ave.
Charleston, S. C.

A ROENTGENOGRAPHIC SPINAL FIXATION AND STABILIZATION DEVICE

By LIEUTENANT COLONEL WEAVER A. RUSH
Medical Corps, Army of the United States

IN THE Roentgen Department of the Station Hospital, Fort Leonard Wood, Missouri, 5,382 individuals have required roentgen examinations of a part or all of their vertebrae during the period from January 1, 1943, to June 1, 1944. Routine and special studies all required accurate positioning for correct roentgenographic exposures. One position seldom sufficed. Multiple positions were the rule. Conservatively estimated, 3.5 positions per person were required, a total of 18,837 for the group of 5,382. January 1, 1943, to June 1, 1944, provided 466 regular working days in this department. Within the group, however, is an undetermined number of emergency exposures made on Sunday. Roughly estimated, 40 positions daily were required.

Only one capable, well trained, experienced technician had been assigned to the Roentgen Department during this period. All others were totally untrained or had very little training. Many soldiers have received their only training in roentgen-ray exposure technique during their assignment here. Most of these have gone to carry on this work elsewhere and were replaced by men equally untrained.

Instructing men with no, or very little, knowledge of anatomy, roentgen-ray anatomy in particular, was a difficult problem. Their training included instruction in proper positioning. Stabilization and fixation so important in the production of adequate reontgenograms had to be simplified in order to prevent loss of time and materials.

First, we solved this problem so far as stabilization and positioning of the skull was concerned. A simple, efficient, fixation device overcame these difficulties, and we next undertook to provide means for simplifying positioning and stabilization of the spine and pelvis. It was necessary that any method adopted be one that would result in identical positioning regardless of changing technician personnel. We feel that we have accomplished this and in addition there has been an increase in diagnostic quality of the roentgenograms produced.

The positioning device described and illustrated requires that roentgenograms be made with the patient standing. Some objection will be raised to this by radiologists who have not enjoyed the advantages of roentgenograms so made. Patients too ill to stand, will, of course, have to be positioned lying down but these are in the minority.

The device comprises a platform of adequate size mounted on casters. This platform may be fixed in a chosen location by a rubber shod foot, screw controlled, at the extreme frontal limits of the platform. This foot not only secures the device in location but prevents forward tipping when the patient mounts it.

Immediately above this platform a second platform is provided, also mounted on casters or suitable rollers. This platform may be moved forward or backward upon the lower platform by a suitable ratchet device. The necessity for this movement will be developed as description proceeds.

Above this second platform another rotatable disk platform is again mounted on casters or roller bearings. It rotates on a vertical central pivot.

A tubular shaft is affixed to the periphery of the disk and adequately braced. A sliding shaft, nonrotatable, is sheathed within the tubular shaft. It is adjustable for height and provided with set screw fixation. To the top of this shaft is welded a flat metal strip of adequate width and length accurately adjusted to coincide with a plane parallel to the surface of the rotatable disk and directly above a line drawn through a diameter of the disk that would bisect the base of the shaft.

To this flat bar is fitted a sliding saddle, preferably of wooden construction, shaped to meet the anatomical contours of the fronts of the thighs and perineal crotch. This saddle is adjustable both forward and backward. It will be noted (see Figures 1, 2, 3 and 4) that degrees of rotation are indicated by suitable symbols on the surface of the platform that supports the rotatable disk and that an indicator points, fingerlike, from the exact center of the base of the shaft. The purpose of this protractor scale and indicator is obvious.

Solidly affixed transversely to the frontal extremity of the flattened bar at the top of the adjustable vertical shaft is a cylindrical hub housing an axle. At its extremities the axle is perforated to receive sliding rods; also thumb screws are properly positioned to lock these rods. This accessory provides an adjustable head and upper spine fixation attachment. The attachment has a cross bar connecting the upper limits of the rods. Stabilization is accomplished by extending the rods to a suitable height and angle so that the patient may bite firmly on the rod which is covered by 4 inches of split rubber tube. A number of these rubber tube cushions are always available, cleaned and sterilized.

The patient is instructed to remove all clothing, including shoes, step upon the disk, mount the saddle and draw it up into his crotch firmly. It is important that he do this himself. Having accomplished this, a web belt is passed around the thighs, snug-

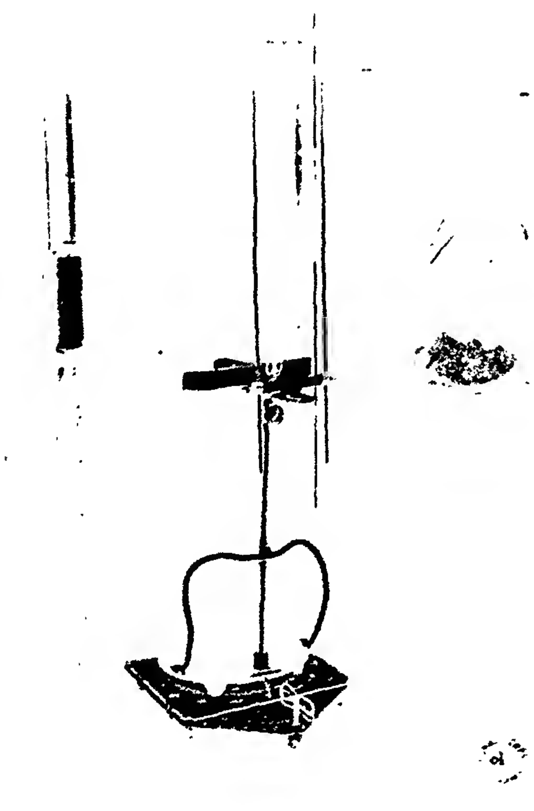

Fig. 1. Frontal view of device.

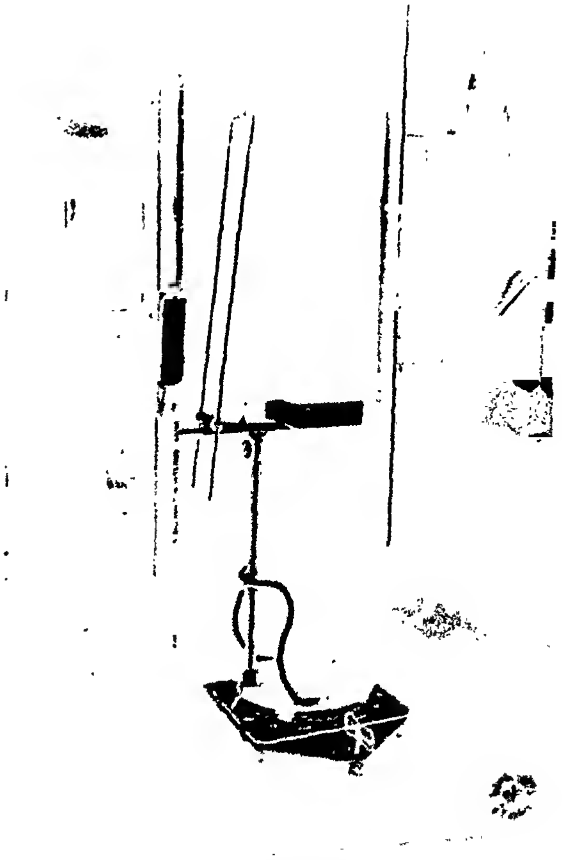

Fig. 2. Lateral view of device.

Fig. 3. Frontal view with patient in position.

Fig. 4. Lateral view with patient in position.

ly drawn and buckled in front of the flat frontal surface of the saddle.

The patient is positioned before a vertical Potter-Bucky grid, the indicator pointing to 0 degrees on the scale. The second or ratchet adjustable platform is moved backward or forward as seems desirable. The saddle is adjusted so that the buttocks are in contact with the surface of the Potter-Bucky grid. The roentgen tube is accurately centered for an anteroposterior exposure. Lateral positions are provided by the simple procedure of rotating the disc 90 degrees. Angle roentgenograms are made at any desired degree selectively and these angles can be accurately reproduced at will at later examinations by referring to the recorded angle and re-establishing this.

The entire spine may be examined at nearly all angles without requiring maneuvers more complicated than the simple act of rotating the disk. Anteroposterior roentgenograms of the atlas and axis through the open mouth are not made by using this device.

The device described has the following advantages:

1. It is of simple construction. No expensive materials are required.
2. Technicians quickly master the simple instructions required to familiarize them with its use.
3. Fixation and stabilization are assured. A multiplicity of positions may be obtained by very simple maneuvers.
4. Very accurate posteroanterior, anteroposterior, lateral and angle positions are assured, all of which can be faithfully reproduced at will.
5. Economic advantages are obvious.
6. Its use provides an accurate means of measuring leg length, recording variations as small as 2 mm. The importance of inequalities in the length of legs is becoming increasingly evident in analyzing architectural instability as a determining factor in low back symptoms.
7. Roentgenographic reproduction of roentgenoscopically predetermined chest positions is accurately accomplished.

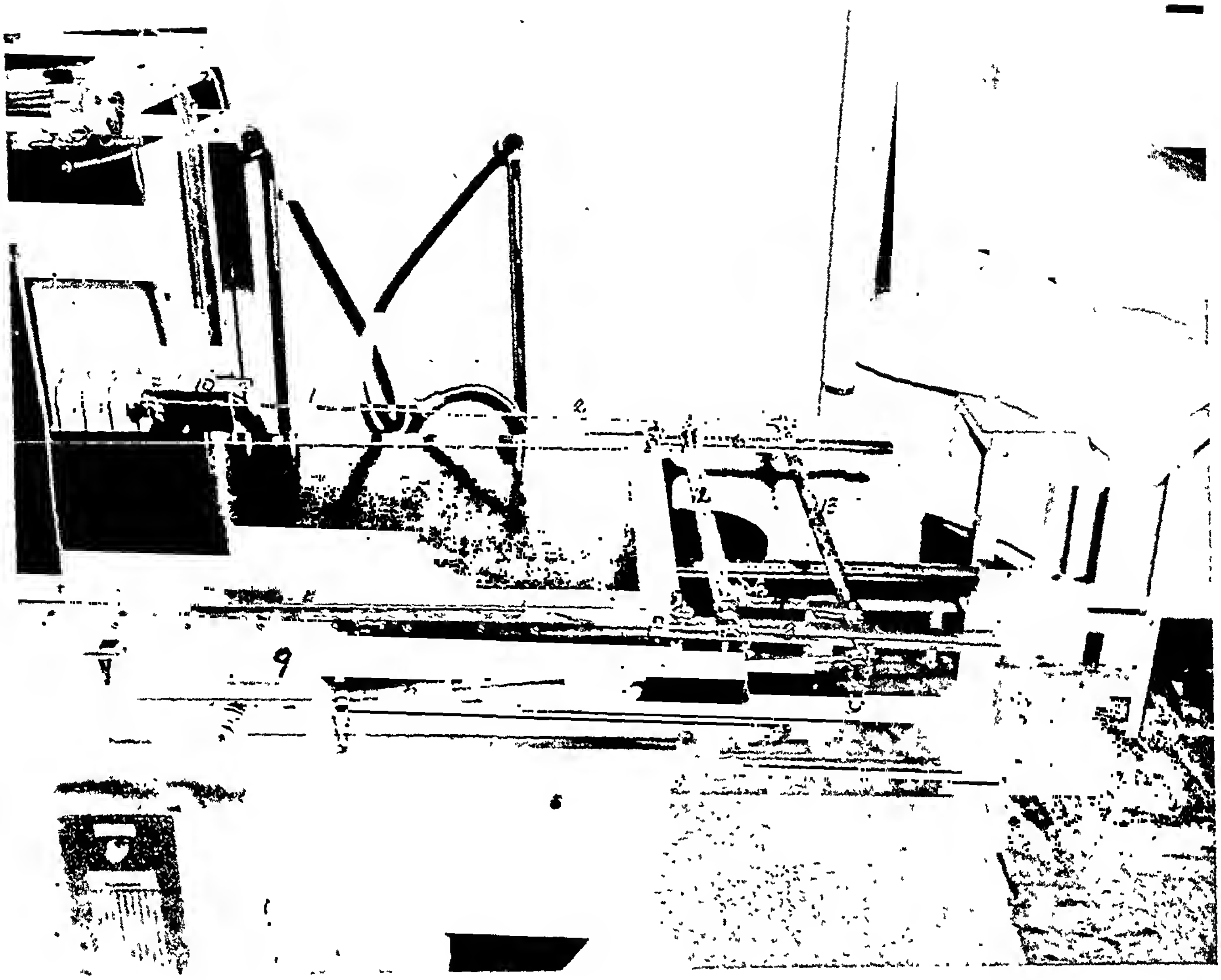

FIG. 2. This photograph shows the parts completely assembled in position for use.

have the additional information of body section roentgenography but do not feel that they can construct a new planigraph on each change of station or for each new installation of equipment.

This apparatus has accompanied the author on all of his changes of station with no more difficulty in transportation than is found with moving textbooks. It has been used on the following makes of equipment to date: Picker Century single tube, Westinghouse Fluoradex, Keleket, and Picker Combination. With this experience there is sufficient evidence to indicate that it could probably be used with any standard equipment. In many instances it has proved of value as an additional diagnostic aid.

The accompanying photographs will show how the apparatus can be assembled. Figure 1 shows the separate parts. These parts are numbered consecutively with corresponding numbers on the assembly shown in Figure 2. *1* and *2* comprise the long rod extending from the lever arm, *13*, to the tube stand and can be lengthened and shortened at either end, and in the center. *3* and *6* are fitted with a hook at each end to fit the side rail. These are the same as the hooks of the foot plate used for tilting the patient from upright to recumbent position. The bar, *12*, has holes drilled to allow the fulcrum, *4*, to be attached. This should be made so that it will be rigid when fitted in place. This has been accomplished here by inserting a small set screw at the base to take up any slack that is present. The bar, *13*, forming the lever arm has holes at each end for the attachment of *2* and *5*, and holes drilled 1 cm. apart for the adjustment of the lever arm to vary the

height of the plane above the table top. *5* is the rod attached to the Bucky tray by means of a removable clamp, *9*. *8* is a screw with a small hook on the end to hold the side pieces *3* and *6* snug to the side rail of the table. *10* and *11* are "U" bolts which hold a small projecting arm on the tube stand for attachment of *1*.

It is easy to see that this entire assembly merely constitutes a framework for the free operation of a lever arm to move the tube and plate synchronously in a reciprocal motion. The measurements can be easily obtained directly by measuring the distances on any standard table. The important point to remember is that the distances should be measured with the tube centered over the Potter-Bucky grid. Inasmuch as different tables vary slightly in size, those parts which form the lever arms should be adjustable, and all other parts that interconnect should be adjustable. The main parts used here were fabricated from cold rolled steel or pieces of metal from salvaged equipment.

The author wishes to express his appreciation for the invaluable help given in designing this apparatus by Dr. S. A. Morton and Mr. Dudley Slauson of the Department of Radiology, Columbia Hospital, Milwaukee. Credit for the mechanical work and fabrication of the various parts should go to members of the Ordnance Corps of the United States Army.

INDEX TO ABSTRACTS

ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

HEAD

Schwartz, Charles Wadsworth. Pitfalls to be avoided in the roentgen diagnosis of intracranial disease. *Radiology*, Jan., 1944, *42*, 34–41.

There are many conditions that may lead to mistaken diagnosis in the roentgen interpretation of findings in the skull. In the first place no conclusions must be drawn from an inadequate set of roentgenograms or those made by poor technique. Nor must they be drawn from a study of only one part of the skull. Every part must be carefully studied and the search must not be given up after finding one anomaly for there may be several, all or none of which may be of clinical significance.

An arbitrary normal zone has been decided upon for the location of the pineal body but this normal zone is too large for absolute accuracy. The body may lie within the normal zone, even if there are pathological changes and it may lie slightly outside the normal zone without such changes. A lateral pineal shift can be detected easily in good roentgenograms taken either anteroposteriorly or posteroanteriorly.

Anomalous appearance of the veins may be misinterpreted. Not infrequently the diploic venous channels are larger than normal. If there is an area of hypervascularity that is of real pathological significance, there is usually some bone reaction near it, such as spiculation or atrophy. To be considered really hypervascular an area must be hypervascular in comparison with other areas of the same head, not in comparison with any arbitrary standard.

The diploe may be coarse or fine, plentiful or scanty, regularly or irregularly distributed. These possible variations must be considered in interpreting the roentgenogram. A fine diploe may suggest that the calvarium is granular and arouse the suspicion of hyperparathyroidism or other disturbance of calcium metabolism. The coarse type of diploe may suggest spiculation, porosity or fibrotic changes in the bone. Careful stereoscopic study will generally reveal the mistake.

Not infrequently in lateral views of the skull there are fine lines at various angles to the plane of the vault that suggest bony spiculations or striations of the type seen in the erythroblastic anemias. But they are caused by a particularly well serrated sagittal suture and the appearance of the bone is healthy. Persistent or double suture lines may suggest fracture and the differentiation must be made carefully. The malar bone may originate from two or three centers of ossification and the appearance may suggest fracture. The congenital lack of a superior orbital plate, as well as other anatomical anomalies, may lead to confusion. Convolutional impressions are often misinterpreted as being evidence of increased intracranial pressure when they are not. An increase in depth and number of these markings may occur in malacic disturbances due to defective calcium metabolism. A demineralized sella turcica may also be misinterpreted as a sign of pressure atrophy when it may be due to a systemic abnormality of calcium metabolism. Atrophy first becomes apparent in the posterior clinoid processes and dorsum sellae and if the cortex of these parts is less dense than that of the adjacent bone it indicates atrophy.

Symmetry of the skull is never perfect, so care must be exercised in interpreting asymmetry as abnormal. About 10 or 15 per cent of skulls show congenital asymmetry of the petrous pyramids. Asymmetry may be of considerable clinical significance if it results from agenesis or hypoplasia of one cerebral hemisphere. This is sometimes seen in patients with convulsive disorders. Asymmetry of the frontal cells is not of much significance but the size and shape of the frontal cells may give evidence as to the endocrine condition of the patient.—*Audrey G. Morgan.*

Camp, John D., and Nash, Leo A. Developmental thinness of the parietal bones. *Radiology*, Jan., 1944, *42*, 42–47.

Developmental thinness of the parietal bones is of two types, the flat type and the grooved type as seen in the posteroanterior projection. It is usually bilateral and symmetrical and there is a smooth, progressive thinness from the periphery of the affected area to its center. The diploe is lacking in the affected area and the external table is thinned and depressed. Some authorities have claimed that the internal table is also affected but this was not true in the 119 cases examined by the authors. The condition can be shown by the usual lateral and posteroanterior roentgenograms of the head, though it can be shown better by tangential views over the affected part of the skull. It is better to examine the roentgenogram by means of a small bright lamp than by the roentgenographic viewing box. Roentgenograms of the two types of thinness are shown and diagrammatic sketches showing the areas involved.

This has often been described as an old woman's disease but of the authors' cases 80 were in males and 39 in females. The average age for the whole group was fifty-four years and for the females fifty-six years. Ten of the patients were thirty years of age or less. One patient was a four year old child.

The condition is not of particularly great clinical importance except that it may be mistaken in the roentgenogram for osteolytic metastatic carcinoma, myeloma, xanthomatosis, osteoporosis circumscripta and a number of other pathological conditions of the skull. The authors believe the condition is not progressive as it was as intense in their younger as in their older patients, and there was never thinness of such a degree as to be classified as a parietal foramen. They believe there is no relationship between these two conditions.—*Audrey G. Morgan.*

Brunner, Hans. Chronic osteomyelitis of the skull. *Ann. Otol., Rhin. & Laryng.*, Dec., 1943, *52*, 850–894.

Chronic osteomyelitis differs from the acute form in almost every respect. Therefore, the differential diagnosis between the two types, as a rule, does not meet with great difficulty. However, among the cases of chronic osteomyelitis there seem to be two different types: one type which presents the typical features of an acute osteomyelitis at the onset of the disease, and another type which does not. In order to differentiate these, the latter type is called "chronic osteomyelitis of primary type" and the former "chronic osteomyelitis of secondary type."

Chronic Osteomyelitis of Primary Type.

Etiology. Infection of the paranasal sinuses is less important than in acute osteomyelitis. In the case reports presented in this article, 1 was due to erysipelas of the skull, 1 to scarlet fever, 1 to a head injury, 1 to adenocarcinoma of the paranasal sinuses with subsequent obstruction to both nasofrontal ducts, 1 to a skull injury, and 2 to pansinusitis.

Clinical Course. Chronic osteomyelitis of the primary type is chiefly characterized by its insidious onset and by its slight tendency to spread.

Pathology and Roentgenology. The normal frontal sinus of adults is bounded by a broad line which has double contours and presents the marginal compacta. In roentgenologic terminology, the margins of the frontal sinus are distinct. The margins of the small frontal sinuses in children and in young adults are partially indistinct under normal circumstances indicating the absence of a marginal compacta. Therefore, in instances of a small frontal or sphenoid sinus a partial indistinctness of the boundaries does not necessarily indicate a pathological condition of the bone even if there is a slight haziness of the sinus, the latter finding being due to the small diameter of the sinus.

In chronic sinusitis a fuzzy appearance of the boundaries and a sclerotic area, particularly at the lateral and superior angles of the frontal sinus, can frequently be observed. This finding indicates a marginal osteitis provided the sinus

has reached its complete development and is definitely cloudy.

In actual chronic osteomyelitis all these changes reach a climax. The outlines of the sinus may disappear entirely and due to the thickening of the anterior wall, the area of the frontal sinus is replaced by a sclerotic area. Frequently the report of the roentgenologist indicates a failure of development or an absence of one frontal sinus in these instances.

Treatment. The osteomyelitis in these cases may continue for years without leading to an intracranial complication. Thus, the operative procedure which may be required is not an emergency performance. The immediate purpose of surgery is to relieve the patient of pain and toxemia.

Chronic Osteomyelitis of Secondary Type.

Etiology. Acute infection of the paranasal sinuses (organism either hemolytic streptococcus or staphylococcus in the cases reported).

Clinical Course. Acute onset, a slow but definite tendency to spread within the bone, and a marked tendency to spread within the blood (viz., chronic septicemia).

Pathology and Roentgenology. The study of the roentgenograms seems to indicate that the pathology is very similar to that of chronic osteomyelitis of the primary type. The infection in both instances produces osteoclasis and osteogenesis, the latter being predominant. Due to these changes, thickening and sclerosis is caused, on the one hand; sequestra, on the other. However, there are some points of difference between chronic osteomyelitis of primary and secondary type. While in the former the sclerosis is to be found in the boundaries of the frontal sinus and spreads extremely slowly into the surrounding parts, in the latter the frontal sinus may regain its normal appearance while the sclerosis and sequestra are to be found in the distant parts of the skull, as in the vault or in the malar bone or in the wings of the sphenoid. Therefore, in instances in which a roentgenogram is taken several years after the onset, the boundaries of the frontal sinus may appear distinct, although the disease undoubtedly originated in the frontal sinus.

Treatment. Treatment in these cases is extremely unsatisfactory. There are a chronic septicemia, a widespread osteomyelitis and, as a rule, metastases which may eventually also serve as the origin of septicemia. It is obvious that under these circumstances surgery cannot accomplish very much.—*Mary Frances Vastine.*

EPSTEIN, BERNARD S., and KULICK, MAX. Technic for optic foramen roentgenography. *Radiology*, Feb., 1944, *42*, 186–187.

The authors describe a method of roentgenography of the optic foramen which obviates the necessity for mechanical devices and gives fairly uniform results. The cassette is placed on a 2 inch block and a cone with a 3 inch aperture focused so that the central ray passes through the center of the film. The tube and cone are elevated and the head placed so that the malar eminence, the tip of the nose and the superior orbital ridge form the apices of a roughly equilateral triangle in the circular roentgen field. The orbital ridge is then raised 1 inch from the cassette. It may be kept in this position by a wedge of felt. In this way the central ray is directed perpendicularly downward. On the roentgenograms the optic foramina appear as circular structures in the lower part of the orbits. The same results have been obtained with an angle board using a 15° angle. The inclined plane is grooved so that a cassette can be inserted. The center of the roentgen field is marked by a cross. The tube is centered over the cross and the head is placed so that the superior orbital ridge, the tip of the nose and the malar prominence are in contact with the inclined plane, the orbit being in the middle. A lead mask may be used to pre-expose the films so that the finished roentgenogram shows a black periphery. The angle board can be made in any carpenter shop.

Photographs of the patient in position and roentgenograms of the optic foramina are shown. The physical factors are 55 kv., 50 ma-sec., cone 7 inches long with 3 inch opening.—*Audrey G. Morgan.*

BERKOVE, ALFRED B. Hypertelorism. *Arch. Otolaryng.*, Dec., 1943, *38*, 587–589.

This is a case report of hypertelorism seen in the Eye, Ear, Nose and Throat Clinic of the Station Hospital, Camp Beale, California. Hypertelorism is a congenital abnormality, the diagnosis of which is made evident by the facial appearance. The condition may be defined as a craniofacial dysostosis resulting from the overgrowth and early ossification of the wings of the sphenoid bone.

The roentgenologic findings seen in this ab-

normality consist of: (1) overgrowth of the lesser wings of the sphenoid; (2) separation of the orbits (large interpupillary distance); (3) excessive width at the base of the nose (with distortion of the tip. In most cases there is a divergent squint).—*Mary Frances Vastine.*

McNally, W. J., Stuart, E. A., and Childe, A. E. Mucocele of the frontal sinus. *Arch. Otolaryng.*, Dec., 1943, *38*, 574–586.

Recently at the Royal Victoria Hospital a mucocele of the frontal sinus was operated on and the sinus was found to be empty. This was the second such case in the past two years. There is much difference of opinion as to just what constitutes a mucocele. One of the best definitions is that of Dabney: "the accumulation and retention of mucous secretion within an accessory sinus, generally associated with a distention of one or more of its walls." Eleven cases of mucocele of the frontal sinus have been diagnosed in this hospital over the past twenty years. Five cases are reported by the authors.

Etiology of Mucocele. Unknown. There are probably a variety of causes.

Symptomatology. The symptoms of mucocele are few.

1. Slowly developing periorbital swelling which is usually painless.
2. The floor of the sinus is usually distorted. The posterior or anterior wall may also be affected.
3. Exophthalmos from deformity of floor of sinus.
4. Fluid contents which may be sticky and mucous, dark and bloodstained or mustard-like in substance.

Differential Diagnosis.

1. Cystic dilatation of the lacrimal sac in which the swelling first appears at the inner angle of the eye. This is below the level at which a mucocele breaks through (either the anterior ethmoid cells or the inner end of the floor of the frontal sinus).
2. Tumor and abscess within the orbit in which case·exopthalmos is present without necessarily deforming the floor of the frontal sinus.
3. Tumor of the frontal bone can be differentiated roentgenographically.
4. Epidermoid cyst (cholesteatoma) is usually present from birth and increases in size gradually. It is more likely to be found in the region of the outer canthus.
5. Meningocele is usually present at birth. It is in the midline and appears above the bridge of the nose. It is cystic and pulsates when the child is at rest. During crying the tumor expands.
6. Meningioma (meningeal fibroblastoma) is unusual in the frontal sinus area. Since it arises within the skull there may be signs of intracranial involvement before there is any external swelling.

Roentgenographic Observations.

1. Dilatation of the whole or some portion of the involved frontal sinus. The opposite frontal sinus may also be involved.
2. The cavity is smooth walled with a slightly whitened margin. It is relatively translucent.
3. The bony septa ordinarily present in the frontal sinus are obliterated.
4. The bony walls may be thinned out and bulged. Defects in the bone may result. The floor is usually primarily involved.
5. The roentgenographic differential diagnosis between epidermoid and mucocele is not easy to make. This is true because the margin of the epidermoid is usually smooth and dense and the tumor is radiotransparent owing to its high cholesterol content.

Treatment. This consists of adequate and permanent drainage which can be obtained only by an external operation.—*Mary Frances Vastine.*

Windeyer, B. W. Malignant tumours of the upper jaw. *Brit. J. Radiol.*, Dec., 1943, *16*, 362–366.

In the Skinner Lecture for 1943 the author discusses a series of 153 consecutive malignant tumors of the upper jaw. By this he means carcinomas and sarcomas originating from the walls or within the cavity of the maxillary antrum; as it is frequently impossible to determine the site of origin of a growth involving both the antrum and the ethmoid region, he has included ethmoid tumors. A consideration of these cases shows the necessity for complete cooperation between surgeon, pathologist, roentgenologist and radiotherapist.

In this series there were 81 males and 72 females, not a great enough difference to be of any significance. No determining cause for the growth was found. There were few cases with a history of sinus infection and repeated operation for the removal of polyps. A number of

cases are illustrated showing the direction in which the tumor grows, depending on its point of origin. The symptoms also vary, depending on the part involved. There is generally pain from involvement of the branches of the fifth nerve. If the spread is in the anterolateral direction the pain is referred to the upper teeth and over the cheek. With spread through the posterolateral wall there may be earache and pain referred to the upper molar teeth on the affected side. This in combination with trismus and the frequency with which a tumor in the temporal region is overlooked may lead to a mistaken diagnosis of dental sepsis. Tumors in the ethmoid region are frequently associated with severe headache and a foul-smelling nasal discharge. When the site of the primary growth is the orbital plate double vision may be the first symptom.

The proportion of sarcomas to carcinomas in this series was lower than in the majority of reports. Metastases were found both in the regional lymphatic glands and in distant organs. A clinical diagnosis of cervical gland metastases was made on admission in 45 of these cases and found in 5 others later, making a total of 32.7 per cent. Probably some of these glands were enlarged as a result of secondary infection. There were generalized metastases in lungs, liver, kidneys and bones in 14 cases, or 9 per cent. Some of the patients had both glandular and distant metastases and the total number of cases with metastases was 59, or 38.6 per cent. —*Audrey G. Morgan.*

Lederman, M. Adenolymphoma of the parotid salivary gland. *Brit. J. Radiol.*, Dec., 1943, *16*, 383–385.

Adenolymphoma of the parotid gland is one of the rarer forms of salivary gland tumor and further information in regard to the effects of surgical and radiation treatment in these tumors is urgently needed. Four cases treated in the Radium Department of the Royal Cancer Hospital are described. The first was a malignant case in a man of sixty-six. Malignant cases are unusual. He was first given treatment with teleradium, 1 gm. unit; surface dose 2,000 r in nine days. There was little or no effect until larger doses (4,000 r or more) were given. In spite of the malignant nature of the case the patient was kept alive for ten years. The other 3 patients with benign adenolymphomas were a woman of fifty-four, a boy of fourteen and a woman of forty-two. Two of these were recurrent after previous operation. Experience in these cases seems to indicate that benign adenolymphomas may be expected to respond satisfactorily to doses of about 5,000 r, using either postoperative implantation over a period of seven days or less, or external irradiation over a period of three to four weeks.

It may be necessary to use radium as the sole method of treatment for an inoperable recurrence, for a benign tumor if operation is contraindicated, for the rare malignant tumor if inoperable. It may be used as a postoperative measure when excision in a given case is known to have been incomplete, for routine use in benign cases if the recurrence rate after excision is shown to be high enough to justify this step. —*Audrey G. Morgan.*

NECK AND CHEST

Fawcitt, Richard. Radiological evidence in haematite iron-ore workers. *Brit. J. Radiol.*, Nov., 1943, *16*, 323–330.

The author discusses the findings in the lungs of hematite iron workers in the Furness and South Cumberland region of the Lake District in England. He formerly examined many of these workmen and labelled them silicotics. He finds now that the condition is a siderosis, that is a fibrosis of the lungs as a result of iron-ore particles or hydroxid of iron in the lungs, apart from an abnormally high silica content with its accompanying glandular changes. This condition was found to be worse in the Cumberland mines than in the Furness mines. This is probably because the Cumberland mines are much drier than the Furness mines and dry drills are used which blow fine dust into the miners' faces which is inhaled. In the Furness mines they use wet drills in which a stream of water runs along the side of the drill and prevents the dust from flying.

Roentgenograms of a number of these cases are given. Hematite is radiopaque and the first stage of siderosis shows increased lung reticulation which progresses to a stage suggestive of small nodes. The author calls the picture snowflake mottling. In damp mines of low silica content there are exaggerated linear markings sometimes associated with snowflake mottling. This indicates the possibility of infection which is always a danger. The next stage shows small patches of coalescence with snowball effect in the upper lobes and emphysema of the bases.

The patches of coalescence become more extensive and compact. At this stage superadded infection is likely and is indicated by spread of the opacity to the outer lung fields. Finally in some cases diffuse areas of consolidation develop and the picture of tuberculosis or malignant disease is seen on roentgen examination. The greatest danger is infection with tuberculosis which affects not only the miners but their families ana both morbidity and mortality from this disease are high in these regions. The treatment is symptomatic. The industrialists are trying to do what they can to prevent the development of the condition and valuable research work is being done by their physicians. The men are coming to appreciate the value of the wet drills and it is hoped that the old conditions with dry drills may never be repeated.—*Audrey G. Morgan.*

Camiel, Mortimer R., and Berkan, Henry S. Inhalation pneumonia from nitric fumes. *Radiology*, Feb., 1944, *42*, 175–182.

Acute inhalation pneumonias from the inhalation of noxious fumes are increasing in frequency. Nitric fumes occur commonly in industry but are not toxic unless generated in confined unventilated places. But they may cause serious damage or even death from rapidly fatal edema of the lungs.

The authors describe 2 cases and give illustrative roentgenograms. Both these patients recovered and there was marked improvement in the roentgen findings in a few days. Both the patients were men of forty; the first had been engaged in cleaning metal and had been mixing nitric acid with hydrochloric acid without a mask. The second patient was a welder's assistant who worked in a ship's hold without a mask. The symptoms are headache, dizziness, palpitation and respiratory distress. There is a latent period after exposure of from a few hours to twenty-four hours so the cause of the illness is sometimes not discovered. In both these cases the roentgenograms showed a pseudonodular infiltration that completely filled both lung fields. During the most acute stage the infiltrations varied in size from that of a match head to that of a pea. In many areas they were confluent and formed larger patches but the nodular character was still evident. Clinical improvement occurred at the same time as improvement in the roentgen picture. Follow-up examinations after some months showed complete absence of residual changes in the lungs.

Such cases show the necessity for prophylactic industrial measures.—*Audrey G. Morgan.*

Schmidt, Herbert W. Benign nontuberculous bronchial stenosis. *Arch. Otolaryng.*, Jan., 1944, *39*, 43–52.

In the past, syphilitic bronchial stricture has been described. At present, much is being written about tuberculous bronchial stricture. Not much attention has been called to stricture produced by nonsyphilitic and nontuberculous inflammation of the bronchi. This type of stricture may develop secondary to a chronic bronchial infection such as that seen in cases of chronic asthmatic bronchitis. Secondary and tertiary bronchi are principally involved. Primary bronchi are occasionally involved. One must assume that the inflammatory reaction throughout the bronchial wall must have been severe enough to cause fibrosis with subsequent stricture. Stagnation of bronchial secretions probably also plays an important part in the genesis of this type of lesion.

This paper is based on a study of 25 cases of benign nontuberculous bronchial stenosis in which bronchoscopy was performed. Four of these cases are reported.

Symptoms. The syndrome of benign nontuberculous bronchial stenosis is a rather definite one. There is usually a history of antecedent pneumonia, severe tracheobronchitis or repeated seizures of asthmatic bronchitis. After variable periods, recurrent bouts of chills, fever and general malaise develop. The period of fever is usually preceded by an irritating, nonproductive cough. The temperature may reach 102 to 103° F., and the elevation may persist for two to seven days, at the end of which time variable amounts of purulent secretion are coughed up. In an attack there is stagnation of infected material distal to the stricture of the bronchus. A local pneumonic process develops.

Physical Findings. Benign nontuberculous bronchial stenosis is more likely to occur in the lower lobe than in the upper lobe or in the middle lobe of the right lung. Physical findings may be absent, since the stenosis usually involves the third division of a bronchus. If physical findings are present, they usually are those of obstructive atelectasis, namely, dullness on percussion and decrease in breath sounds over

that portion of the lung supplied by the involved bronchus.

Roentgenologic Findings. In obstructive atelectasis the physical findings may be of more value than the roentgenologic findings. Roentgen examination is important in determining the presence of atelectasis, but the roentgen findings alone will not always enable one to determine whether or not a bronchus leading to the affected region is open or closed.

The roentgen findings in obstructive atelectasis may be listed as follows: (1) The pulmonary field is reduced on the affected side. (2) The heart and mediastinum are displaced toward the affected side. (3) There may be narrowing of the intercostal spaces with increased downward angulation of the ribs. (4) There are elevation and decreased motion of the diaphragm on the involved side. (5) The atelectatic region itself will show increased density. (6) The trachea is displaced toward the side of the lesion. (7) On inspiration, the heart is drawn toward the affected side, and on expiration the mediastinum moves away from this side. (8) Bronchography may help to determine whether or not an obstruction exists and to localize the site of obstruction.

Bronchoscopic Findings. Bronchoscopy is the only clinical method of determining whether or not benign bronchial stenosis exists. The involved bronchus is seen to be reduced in size or it may be completely closed. It has a rigid appearance; that is, it does not increase in size during inspiration and decrease in size during expiration. Almost always there is a trickle of purulent secretion coming from its orifice. When touched, the bronchus bleeds more readily than the normal.—*Mary Frances Vastine.*

CUTLER, J. W. The harmful influence of pregnancy on advanced tuberculosis as modified by collapse therapy. *Am. J. Obst. & Gynec.*, Jan., 1944, *47*, 1-19.

This presentation concerns itself with the effects of pregnancy upon advanced tuberculosis in a series of 26 white women who were treated with collapse therapy. [illegible] gave birth to [illegible] children [illegible] and well. The study [illegible]

1. Pregnancy [illegible]

2. Collapse therapy has [illegible] the risk and has brought a [illegible] expectant tuberculous mother.

3. If the disease [illegible] to one lung, as indicated [illegible] tion, and the diseased [illegible] well collapsed with [illegible] tum free of tubercle [illegible] maintained throughout [illegible] little or no risk of [illegible] and such women may [illegible] more pregnancies. The [illegible] advanced tuberculosis [illegible] the disease in each lung [illegible] quate collapse therapy. In [illegible] the interval of effective [illegible] safest period for a tuberculous [illegible] have children, and [illegible]

4. If there is disease in both [illegible] one lung is treated with [illegible] disease in the uncollapsed [illegible] cent before pregnancy [illegible] approximately [illegible] true even if the [illegible] lung is minimal [illegible] months or years [illegible] tubercle bacilli [illegible]

5. The [illegible] tuberculosis [illegible] not in itself a [illegible] Permission [illegible] collapse therapy [illegible] cated.

6. Pregnancy [illegible]

[illegible]

Vineberg, Arthur M., and Kunstler, Walter E. The determination and treatment of pressure cavities in pulmonary tuberculosis. *Surg., Gynec. & Obst.*, March, 1944, *78*, 245–274.

The authors have worked out a new technique of transthoracic intracavitary drainage which requires the use of special instruments in addition to those devised for cavity needling. The instruments used were designed by the writers. Too often large cavities are closed by multiple stage thoracoplasties, the disease is arrested and the patient becomes a respiratory cripple. It is apparent that a more efficient and less destructive method of collapsing cavities is desirable. Such a method seems to be on hand in the form of transthoracic cavity drainage.

This study of pressure cavities in pulmonary tuberculosis is a very complete one and for it, the authors were awarded the Casgrain-Charbonneau Prize 1942 by the Faculty of Medicine, McGill University. The following points are included in the summary:

1. A large percentage of pulmonary tuberculous cavities are "tension cavities" and rarely close with thoracoplasty.

2. Some residual cavities are "tension cavities" which are unaffected by thoracoplasty.

3. The detection of "tension cavities" can be made only by needling of the cavity and recording of the intracavitary pressures.

4. Transthoracic intracavitary suction drainage is recommended only for use in "tension cavities."

5. In 150 instances, cavities were needled and 27 cavities were drained without a single complication of hemorrhage, pleural empyema, spontaneous pneumothorax, or air embolism.

6. Intracavitary suction drainage will reduce large "tension cavities" to the size of a catheter; to obtain permanent closure a partial thoracoplasty is essential.

7. In giant positive pressure cavities, anterior stage thoracoplasty precedes suction drainage and the latter is followed by posterior stage thoracoplasty.

8. Negative pressure giant cavities close readily with thoracoplasty.

9. By the use of a combination of transthoracic intracavitary suction drainage and thoracoplasty in the treatment of "tension cavities" the ideal of collapse therapy is attained, namely, a maximum collapse of diseased areas with a minimum of damage to normal lung parenchyma.—*Mary Frances Vastine.*

Johnstone, A. S. Peptic ulceration of the oesophagus with partial thoracic stomach. *Brit. J. Radiol.*, Dec., 1943, *16*, 357–361.

Peptic ulcer of the esophagus was first recorded by Quincke in 1879 but the combination of peptic ulcer and short esophagus seems to have been first described by Briggs, Dick and Hurst in 1939. There are two schools of thought in regard to the cause of this combination. One holds that it is always the result of congenital shortening of the esophagus so that a part of the stomach is pulled up into the thorax. But Chevalier Jackson reports 21 cases in which there was no coexisting abnormality of the esophagus.

The author has records of 21 cases. He discusses the roentgen findings, which are illustrated by roeentgenograms. On the basis of his findings he concludes that peptic ulceration of the esophagus and partial thoracic stomach are inseparable. They are seen chiefly in elderly people, especially of the sthenic build, in whom the development of hiatus hernia is almost a normal process. The frequent regurgitation of acid, in association with other factors, may cause peptic ulceration which becomes chronic and causes sufficient cicatrization to shorten the esophagus and produce partial thoracic stomach. There is no doubt, however, that in some cases the partial thoracic stomach is congenital. The author reports one proved case in a young man of twenty-three in whom no hiatus hernia was found.—*Audrey G. Morgan.*

ABDOMEN

Levine, Samuel, and Solis-Cohen, Leon. Survey film diagnosis of acute surgical abdomen. *Surg., Gynec. & Obst.*, Jan., 1944, *78*, 76–82.

A minimum of three roentgenograms should be taken: a high and a low supine view and an upright view. In cases in which the patient's condition permits, roentgenograms in the prone and lateral decubitus positions are advantageous. A few of the many interesting points brought out in the article may be outlined as follows:

1. Ruptured peptic ulcers are more often the cause of free intraperitoneal air than ruptured

appendices. When the patient is roentgenographed shortly after the onset of the perforation, no free air may be seen.

2. When air collects beneath the left diaphragm it may be confused with the magenblase; to obviate this, a right decubitus view should be taken.

3. After laparotomy free intraperitoneal air will persist for about ten days.

4. In hepatocolic interposition, care must be exercised in interpreting the upright view.

5. In cases of intestinal obstruction, the more proximal the obstruction, the greater the degree of intestinal dilatation. If there is marked small intestinal dilatation the involvement is most likely jejunal since more secretory activity occurs in the jejunum than the ileum. It is usually abnormal to find gas within the small bowel.

6. Ingested air may traverse the small bowel in six to fifteen minutes.

Morphine may cause gas to appear in both the small and large intestine. Morphine affects, chiefly, the duodenum. The duodenum is first constricted and then dilated by this drug.

8. Ordinarily the ileocecal valve blocks the egress of gas from the small into the large bowel. In sigmoidal obstruction of long standing there may be regurgitation of air into the cecum with marked distention or even rupture of the cecum. Therefore, tremendous dilatation of the cecum on survey roentgenograms should arouse the suspicion of a low colonic obstruction.

9. In a lacerated spleen, the blood gravitates along the gastrolienal ligament so that the greater curvature of the stomach assumes a serrated appearance because of the juxtaposition of the adjacent hematoma. The stomach is displaced to the left and the colon downward.

10. Mesenteric thrombosis yields a picture similar to that of ileus. In this type of case, the small intestinal loops are only slightly dilated. Mesenteric abscess produces a homogeneous radiopaque shadow surrounded by dilated small intestinal loops.

11. Volvulus is invariably associated with considerable elongation and reduplication of the sigmoid. In this condition, markedly dilated loops of large intestine usually are seen near the hepatic flexure.

12. In tuberculous adenitis, one may encounter complete duodenal obstruction resulting in marked gastrectasis.

13. A ruptured abdominal aneurysm may simulate an acute surgical abdomen. The roentgenogram shows a diffuse homogeneous density to the left of the lumbar spine obliterating the left ileopsoas line.

14. In atresia of the sphincter and in the newborn, it may be advantageous to examine the patient in the Trendelenburg position; distention of the large bowel including the rectal ampulla, the column of air stopping short of the anus, may be noted.—*Mary Frances Vastine.*

Brindley, G. V. Acute obstruction of the colon. Editorial. *Surg., Gynec. & Obst.*, May, 1944, *78*, 556–558.

It is conservatively estimated that 20 per cent or more of the patients with acute obstruction of the colon lose their lives.

Etiology of Large Bowel Obstruction. The etiology is quite varied. However, a fact worthy of emphasis is that carcinoma produces obstruction in this part of the intestinal tract in 80 per cent or more of the cases. About 10 per cent of all malignant lesions of the colon produce obstruction and, of these obstructions, 7 out of 8 are in the left half. Obstructions of the colon due to malignant disease occur mainly in elderly persons for 70 per cent of the patients with cancer of the colon are over fifty years of age. The next most frequent causes of obstruction in this region are volvulus, diverticulitis, chronic inflammation, benign strictures, and intussusception.

Clinical Features of Obstruction. The symptoms develop more slowly in occlusions of the large intestine than in those which occur in the small bowel. However, when the obstruction has persisted long enough for the blood supply of the intestine to become impaired, the patient will frequently pass rapidly into a serious state and in a question of hours his condition may become hopeless. The marked biochemical changes which develop rapidly in obstruction of the small intestine are not seen in occlusions of the colon.

Treatment.

1. Obstruction due to bands usually demands only the severance of the bands.

2. Obstruction due to benign stricture usually requires an entero-anastomosis around the obstructing segment.

3. Torsion of the intestine is treated by a reduction or resection of the volvulus.

4. Obstructions occasionally produced by en-

dometrial adenomas can be controlled by surgical attention to the female generative organs or by means of radiation therapy.

5. Diverticulitis seldom produces complete obstruction and an occlusion due to it can usually be decompressed by medical management.

6. To cure an occlusion of the colon due to carcinoma, it is necessary to resect the lesion widely. Experience has shown that a primary resection of the colon should never be done in the presence of an acute obstruction which is due to a neoplasm for it is unnecessary and the mortality is prohibitive. A cecostomy or colostomy in the transverse colon is indicated to relieve the distention. Usually the obstructed colon is decompressed adequately by this means for a safe resection later.—*Mary Frances Vastine.*

Birnkrant, Milton. Traumatic serous cyst of the lesser omentum. *Radiology*, Jan., 1944, *42*, 74–76.

Serous omental cysts are rarely of traumatic origin. In fact only 1 case has been described before this one. In this case the patient was a carpenter twenty-three years of age. His assistant fell from a scaffold and in so doing struck him in the abdomen with his elbow. He felt severe epigastric pain followed by colic and persistent vomiting. The pain abated and his condition remained stationary until the eighteenth day when he had a recurrence of the abdominal pain and vomiting. A roentgenogram of the abdomen five days after the injury showed the colon distended with gas with the middle part of the transverse colon at the third lumbar vertebra. A barium enema seventeen days later showed the transverse colon at the level of the lumbosacral articulation. It was concave upward and the haustral markings were lost. There was a diffuse homogeneous opacity in the upper abdomen. The findings were thought to indicate a mass depressing the transverse colon.

Operation showed the upper abdomen filled by a large round encapsulated mass which depressed the stomach and displaced it forward. The gastrocolic membrane was thickened and infarcted. It formed the anterior wall of the tumor which was found to be a cyst of the lesser omental sac. Five thousand cubic centimeters of straw-colored fluid were withdrawn. The cyst collapsed and the walls were marsupialized. The patient made an uneventful recovery and has been under observation for four and a half years. Roentgen examination at the end of four years showed the transverse colon in normal position with return of the haustral markings.

There may have been a pre-existing small simple serous cyst, but even if there were, the trauma was of primary importance in creating the condition found on operation.—*Audrey G. Morgan.*

Huidobro, F., Montero, E., and Cuevas, F. The effect of certain drugs on the motility of the jejunoileum in normal man. *Surg., Gynec. & Obst.*, May, 1944, *78*, 471–476.

The movements of the jejunoileum and the action of drugs commonly indicated for use in relation to this part of the digestive tract were studied in 11 normal volunteers without evidence of digestive disturbances. The movements were recorded on a kymogram from a Mary tambour connected with the balloon of a Miller-Abbott tube introduced into the intestine 2.5 to 4.5 feet below the pylorus.

1. Amyl nitrite decreased markedly the intestinal movements and the tonus of the jejunoileum. The effect was brief.

2. Nitroglycerine did not affect intestinal movements.

3. Theophylline ethylenediamine (cardiomine Collier) acted like amyl nitrite but less intensely and for a longer time.

4. Methyl octenylamine (octinum Knoll) and diphenyl diethylaminoethanol hydrochloride (trasentin Ciba) decreased markedly the amplitude of the intestinal movements for more than sixty minutes and tended to decrease the tonus.

5. Pitressin and prostigmine increased the spontaneous motility of the small intestine; the effect of the former was more intense and more constant than that of the latter.

6. Atropine sulfate and morphine sulfate decreased the motor activity of the jejunoileum. The former may cause the exaggerated motility produced by pitressin to disappear, and the latter, in a large dose, may cause the intestinal movements almost to disappear and slightly increase the tonus.—*Mary Frances Vastine.*

Jungmann, H. Hodgkin's disease of the stomach. *Brit. J. Radiol.*, Dec., 1943, *16*, 386–387.

There are few proved cases of Hodgkin's disease of the stomach. A case is described in a man of sixty who for some time had had inter-

mittent abdominal pain and for about two months severe pain around the umbilicus after meals. Otherwise he was fairly well; appetite normal, no vomiting, Roentgen examination showed generalized disease of the stomach of the nature of a hypertrophic gastritis with infiltration of the deeper layers. Roentgenograms are given. The appearance was that of a widely infiltrated cardinoma extending almost to the cardia. Total gastrectomy and splenectomy were performed. Pathological examination showed Hodgkin's disease infiltrating all coats with an especially large number of proliferated reticulum cells.

There are three types of Hodgkin's disease of the stomach: an ulcerative type with multiple flat ulcerations, a tumor-like type usually situated in the prepyloric region, and changes involving the whole stomach which have been described under the heading of polyposis of the stomach. This case belongs to the last type. Although peristalsis was very sluggish in this case it was not entirely absent as it is in cases of extensive malignant infiltration. This may be used as a differential point between Hodgkin's disease and cancer.—*Audrey G. Morgan.*

Good, C. Allen. Entero-enteric intussusception. *Radiology*. Feb., 1944, *42*, 122–127.

The most common type of intussusception, the ileocolic, is generally seen in infants but the entero-enteric type, involving only the small intestine, is frequent in adults and may be chronic. Generally there is some underlying cause for such an intussusception, such as tumor, invagination of a Meckel's diverticulum, enlargement of a mesenteric lymph node, ulceration of a Peyer's patch, stenosis or adhesions. Clinical diagnosis is more difficult than in the other forms as the appearance of blood in the stools occurs late and the tumor is often so small that it is not palpated. Roentgen examination after giving a barium meal by mouth shows gradual narrowing of the lumen of the bowel as it approaches the intussusception; marked narrowing of the lumen through the intussusception; retrograde filling of the space between the intussusceptum and the intussuscipiens and the formation of a "concentric ring" or "spiral sheath" image. There is a palpable mass at the site of the filling defect in the barium. Though the roentgenogram or screen examination shows the insussusception it usually does not reveal the cause of it.

It is not safe to give barium by mouth unless it is known that there is no obstructive lesion in the colon. It is a good idea, therefore, to study the colon by means of a barium enema before attempting to examine the small intestine. If there is no lesion in the colon barium can be given safely by mouth.

Three cases of entero-enteric intussusception are described and illustrated.—*Audrey G. Morgan.*

Hurst, Arthur. Dyschezia andmega colon. *Radiology*, Feb., 1944, *42*, 128–135.

The author criticizes a paper published by Delano, Ronayne and Boland in the December, 1941, number of *Radiology* in which they say that dyschezia is merely a misnomer for megarectum. Hurst holds that these are two entirely different conditions. Dyschezia is difficult defecation caused by neglect or disregard of the conditioned or habit reflex on which evacuation is based. It can be cured by restoring the defecation reflex to activity. Usually an explanation of the physiology of defecation and a restoration of the habit is all that is needed. If the patient is still unable to empty the rectum, even though it is loaded with feces, an enema of a fluid ounce of glycerine should be given in the morning after an unsuccessful effort has been made. The strength of the enema should be gradually reduced until the normal defecation reflex is restored.

Megacolon is due to achalasia of the anal sphincter or a failure to relax when the rectum contracts during defecation. This leads finally to enormous dilatation of the colon and hypertrophy of its walls from the increased peristalsis used in an effort to overcome the obstruction. Improvement in function is the thing to be aimed at in treatment. Once the colon has been greatly distended it remains distensible and if an opaque enema is given it may distend to its former size, giving the patient the idea that nothing has been accomplished. The resistance of the closed anal sphincter must be overcome. This is best attained by the use of a conical vulcanite bougie which is passed every morning after an attempt has been made to evacuate the bowels. It is perforated along its axis to allow the escape of gas from the intestine. After it is passed, a second attempt is made to defecate which is usually successful. In children the colon must often be evacuated by lavage and the use of the finger. Once it is emptied the patient is

usually able to have an evacuation every day. No aperients should be given but it may be necessary to give paraffin to prevent the feces from becoming hard.

Recently various operations have been performed on the sympathetic nervous system with the object of reducing the tone of the anal sphincter. It has been found that when spinal anesthesia is given for these operations the condition is relieved even though no operation is performed. The author advocates giving a spinal anesthetic without sympathectomy when there is difficulty in emptying the rectum and pelvic colon by enemas alone.

On page 190 of the same journal Delano replies to Hurst's criticism of his paper. He holds that Hurst's reasoning is confused and that dyschezia is not a clinical entity.—*Audrey G. Morgan.*

Lichtman, A. L., and McDonald, John R. Fecal fistula. *Surg., Gynec. & Obst.*, May, 1944, *78*, 449–469.

This investigation was undertaken in an attempt to provide a sound basis for the study of the causes of persistence of fecal fistulas and the utilization of this knowledge in the application of the proper treatment for the cure of the fistula. From 1930 to 1941, inclusive, 590 cases of fecal fistula were encountered at the Mayo Clinic. In 58.2 per cent of these the external opening was in the right lower quadrant of the abdomen.

Classification.

1. Cause. Congenital, Most fistulas of congenital origin terminate at the umbilicus and represent a patent omphalomesenteric duct. They are rare. None was found in this series.

2. Acquired. *Pathologic or spontaneous fistulas* follow spontaneous rupture of a section of the intestinal wall due to infection, malignant lesion or impeded circulation. *Traumatic fistulas* include those following gunshot wounds, perforating wounds and fecal fistulas associated with compound fractures and hemorrhages. *Postoperative fistulas* include: (1) intentional, those operatively created for decompression in obstruction, to rest a diseased section of bowel, or prophylactically to protect a freshly sutured bowel; (2) accidental, those following operations involving malignant lesions, and those following inflammatory lesions of the intestines. The fecal fistula usually appears in the immediate postoperative period. Occasionally, however, there is an interval of as much as six to twelve months between the operation and the development of the fistula.

Pathologic Anatomy. The presence of foreign body giant cells laden with small cotton fibers in the wall of persistent fistulas suggests the danger of the vigorous swabbing, grasping, and packing with dry gauze so widely practiced. The lint left behind on the delicate peritoneal surface is visible on careful inspection during an operation. Although cotton suture itself may not arouse much of a reaction, finely divided lint plus pressure or bruising injury to the peritoneum stimulates a proliferative fibrous reaction with the formation of fine adhesions. Combined with the formation of a fistula this rather minor reaction is enough to cause persistence of a fistula otherwise predisposed to heal spontaneously. Similar proliferations are produced by talc, petrolatum, or lycopodium.

Factors which maintain fistulas.

1. There is a distinct, active lesion in the intestinal wall at the fistulous opening which prevents spontaneous closure. Operative closure can be successful only if this diseased segment is excised.

2. Foreign substances such as cotton fiber, talc, lycopodium, petrolatum, and products of degeneration embedded in the fistulous tract itself may alter the processes necessary for spontaneous closure of the fistula.

3. The defect or diseased portion in the intestinal wall may be too large for spontaneous closure, since contraction of scar tissue sufficient to close the fistula would produce constriction of the intestinal lumen. Here also resection of the diseased though quiescent segment of the intestine is essential for closure of the fistula.

Summary. The authors emphasize that in the majority of the cases active intestinal lesions, such as regional enteritis or the presence of some granuloma-stimulating microscopic foreign substance was found. It is maintained that the persistence of fistulas after appendectomy for acute appendicitis is due to an ulcerative or granulomatous lesion of the region, an abscess cavity, gangrene, or constriction of the intestine below the fistula. Fistulas resulting simply from the pressure of drains, misplaced sutures, the nicking of the intestine, inversion of the appendiceal stump or failure to invert it, will heal spontaneously. Persistence of the fistula is evidence of an inherent lesion of the intestinal wall or a microscopic or macroscopic foreign substance.—*Mary Frances Vastine.*

Robertson, H. E., and Dochat, George R. Pregnancy and gallstones; collective review. *International Abst. Surg.*, March, 1944, *78*, 193–203.

It has been frequently stated that "90 per cent of all women who have gallstones have also borne children." The authors decided to test the validity of this generally accepted remark. They analyzed the records of 16,936 cases in which postmortem examination was performed at the Mayo Clinic during the years 1910 to 1942 inclusive. The cases included only those in which opportunity was afforded for the examination of the gallbladder and bile ducts. The following conclusions were reached:

1. Gallstones occur more frequently (twice or three times) in women than in men.

2. Many writers followed Schroeder and Naunyn when they announced that 90 per cent of women with gallstones had also borne children, and all of these writers, therefore, concluded that pregnancy was conducive to the production of gallstones and accounted largely for the increased incidence of gallstones in women.

3. Estimation of the relative number of married women who remained childless (13 per cent) plus the relative number of single women (7.8 per cent) gave the total relative number of women who had never borne children (20.75 per cent); therefore, about 79.25 per cent of all women have had children.

4. This last figure (79.25 per cent) corresponds very closely to the number of women with gallstones who had borne children. This latter figure in the postmortem series was 84 per cent. In the combined series reported by thirty-four authors, 11,154 of 14,016 women with gallstones had had children, an average of 79.6 per cent.

5. There is also some evidence that gallstones occur earlier in women than in men.

6. Thus it would appear that pregnancy cannot account to any great extent for the increased incidence of gallstones in women.

7. The solution of these problems as well as that of the real cause of gallstones still remains a considerable mystery.—*Mary Frances Vastine.*

GYNECOLOGY AND OBSTETRICS

Snow, William, and Nadel, Milton. Roentgen study of the fetus in utero. *Radiology*, Feb., 1944, *42*, 136–142.

The authors have made roentgen studies in over 2,500 cases of pregnancy in which abnormalities were suspected. By such examinations they can determine the size and age of the fetus, fetal death, normal and abnormal fetal positions, extension or deflection of the fetal head, engagement of the fetal head and congenital and acquired diseases.

There is not enough lime in the bones of the fetus for roentgen visualization until it is about fourteen weeks old. From this time on, its age can be estimated from the roentgenogram which should be taken in a lateral view. The fetal size and age can also be determined from the occipitofrontal diameter of the head. Weight can only be estimated and not always with complete accuracy. The first sign of fetal death is overlapping of the skull sutures. Later the spine may become abnormally curved and the fetus may assume positions which are obviously abnormal. The normal and abnormal positions of the fetus and extension and deflection of the head are discussed. Patients are rarely sent for roentgen examination after the head is engaged, for after the head has descended well into the pelvis there is little likelihood of dystocia.

There are many forms of fetal monstrosity and in all cases of cesarean section it is well to make a roentgen examination before operation to avoid delivery of a monster. One of the most common fetal abnormalities recognized in utero is acrania or anencephaly. It shows geometric soft smooth shadows surrounding the fetus and a thick layer of subcutaneous fat manifested by a broad black line of demarcation. Elephantiasis congenita is shown by extensive deposits of fat around the fetus. In symmelus or mermaid there is a greater or less degree of fusion of the bones of the lower extremities. Osteogenesis imperfecta shows deformity of the bones, usually with multiple fractures. In hydrocephalus the head is enormous. Premature closure of the sutures or unusual thickening of the skull may interfere with moulding and cause dystocia. Other abnormal fetal conditions that may be recognized are extensive spina bifida, hemivertebrae, supernumerary digits, syphilis, rickets, and fractures.—*Audrey G. Morgan.*

Moir, Chassar. Fallacies in soft tissue placentography. *Am. J. Obst. & Gynec.*, Feb., 1944, *47*, 198–211.

This study is from the Department of Obstetrics and Gynecology, University of Oxford. A representative series of roentgenograms ... obtained from normal patients in the late ...

weeks of pregnancy. A critical analysis was then made of some 30 roentgenograms selected because of technical superiority. The following conclusions are reached:

1. Experiments show that the dark band surrounding the fetus in utero is the result of the relative transparency of the subcutaneous tissue of the fetus. It does not represent amniotic fluid. The conclusions of Weintraub and Snow are in the main confirmed.

2. Experiments are described which prove that the uterine wall, the placenta, and the amniotic fluid are all similar in radiopacity. a local collection of amniotic fluid (caused by an uneven position of the fetus in utero) gives a shadow indistinguishable on ordinary examination from placental tissue. The shape of the shadow may give a clue to its identity but certainty in diagnosis is seldom possible on this basis alone.

3. Critical examination of previous work raises doubt regarding the accuracy of the interpretation of the experimental finding. In some of the roentgenograms the thickness of the "placenta" considerably exceeds the thickness of the normal organ.

4. The deep indentations frequently seen on the "placental" surface can readily be explained on the basis of the fluid nature of the shadow-producing substance.

5. In test cases, the localized thickening of the uterine wall shadow (the placental site according to the original definitions) disappeared when external pressure was applied.

6. In test cases, air introduced into the amniotic sac revealed a uterine wall of normal thickness at the site of the supposed placenta.

7. Positive findings from this method of placentography should be accepted with reserve; negative findings may have a limited field of usefulness.—*Mary Frances Vastine.*

GENITOURINARY SYSTEM

Abeshouse, B. S. Surgery of the congenital anomalous kidney. *Surg., Gynec. & Obst.*, March, 1944, *78*, 288–303.

It is generally agreed that congenital anomalies occur more frequently in the kidney than in any other organ in the body. The most common renal anomalies encountered are fused supernumerary kidney, polycystic kidneys, congenital hypoplastic kidney, congenital ectopic kidney, and horseshoe kidney. The intrinsic lesion in a congenital anomalous kidney may manifest itself in one or more of the following changes: (1) extensive histopathologic changes associated with defective development of the fetal kidneys, i.e., embryonic, sclerotic or calcified glomeruli and tubules, cystic degeneration, etc.; (2) hydronephrotic atrophy secondary to congenital obstructive lesions in the upper or lower urinary tract; (3) renal atrophy secondary to anomalous blood supply; (4) various types of inflammatory or suppurative lesions of the renal parenchyma due to acquired infection; (5) calculosis secondary to obstruction or infection.

Renal Aplasia and Hypoplasia. Aplasia indicates a faulty developed kidney which is much smaller than normal and is composed of embryonic or calcified glomeruli or tubules. The hypoplastic kidney is well developed from an anatomic and histologic standpoint but is diminutive or infantile in size. The aplastic kidney is usually functionless while function in the hypoplastic kidney is diminished. Renal aplasia is a rare anomaly.

Supernumerary Kidney. When two separate pelves are found to be free or fused on one side, the upper pelvis is usually rudimentary and the parenchyma is hypoplastic, whereas the lower pelvis is well developed and the parenchyma possesses normal or near normal function. When the two pelves are intimately adherent or fused together, the anomaly is known as a fused supernumerary kidney. This is the most common renal anomaly. According to Campbell the incidence is 1 in 195 cases. The surface of such kidneys may be smooth and uniform or show a definite groove or constriction at the junction of the two segments. When the upper rudimentary segment is distinctly separate, the anomaly is considered as a true or free supernumerary kidney.

The ureters in either anomaly may show a complete or incomplete duplication. When complete duplication is present, the ureter of the upper pelvis is straighter and narrower than its mate. The orifice of the ureter to the lower pelvis is most frequently found to be superior and lateral whereas that of the upper pelvis is medial and inferior. The common site of the bifurcation in incomplete duplication is in the upper third and least often in the lower third.

Horseshoe Kidney. This is one of the common renal anomalies. Campbell found 60 cases in 26,480 necropsies. The pathologic changes asso-

ciated with urinary stasis are more frequently noted in this anomaly than in the normally developed kidney. This is due to interference with drainage from the pelvis and ureter which may be caused by abnormal rotation of the pelves, lateral exit of the ureter from the pelvis, and compression of the ureter over the isthmus or by anomalous blood vessels.

Sigmoid Kidney. This is one of the rarest types of renal anomalies. Young distinguishes two types: (*a*) the true sigmoid kidney—each kidney on the correct side of the body but the fused portion is situated in the midline of the body, and (*b*) the unilateral elongated (or fused) kidney—both kidneys fused on the same side of the body—a crossed dystopia.

Renal Ectopia. The ectopic kidney is a congenitally misplaced kidney which has failed to ascend to its normal position. It is usually found within the true pelvis or at the level of the sacral promontory. It is to be distinguished from the acquired dystopic kidney (nephroptosis) whose variable mobility may be due to intrinsic or extrinsic factors. It is generally recognized that slight degrees of congenital displacements are not unusual but marked degrees of displacements are relatively rare. The congenital ectopic kidney is usually unilaterally displaced on the side that it normally belongs, but occasionally may be of the crossed dystopic variety.—*Mary Frances Vastine.*

McDonald, John R., and Priestly, James T. Malignant tumors of the kidney; surgical and prognostic significance of tumor thrombosis of the renal vein. *Surg., Gynec. & Obst.*, Sept., 1943, *77*, 295–306.

In cases of hypernephroma of the kidney, the presence of tumor thrombosis of the renal vein is of definite prognostic significance. The prognostic significance is comparable to that of involvement of the lymph nodes in cases of carcinoma of the breast or gastrointestinal tract.

Method of Study. In order to determine the incidence of tumor thrombosis of the renal vein and the effect of such thrombosis on the ultimate survival rate after nephrectomy for malignant neoplasm, a dissection was made of the vein, artery, and their tributaries in the hilum of every kidney that had been removed because of a malignant neoplasm at the Mayo Clinic in the years 1904 to 1940 inclusive. In all, approximately 700 kidneys were examined.

Hypernephroma. The tumor was a hypernephroma in 509 of 636 cases. Malignant thrombosis of the renal vein was present in 54 per cent of these cases. It is thus not surprising that the lung is the usual site of metastatic involvement in cases of hypernephroma. The artery and lymphatics about the hilum of the kidney were not invaded by this tumor. Bizarre metastatic involvement of the spinal column can readily be explained by anastomosis of the renal veins with those of the paravertebral venous system (Batson).

Carcinoma of the Renal Pelvis. In 11.9 per cent of the series, the neoplasm was a carcinoma of the renal pelvis. Involvement of the lymphatics in the hilum of the kidney or tumor thrombosis of the renal vein or both were present in 44.7 per cent of the cases of carcinoma of the renal pelvis. In these tumors, metastasis usually occurs in the periaortic lymph nodes or in the lungs.

Wilms' Tumor. Tumor thrombosis of the renal vein or involvement of the perineural lymphatics or both were present in 14, or 42.5 per cent of the cases of Wilms' tumor.

Sarcoma. Tumor thrombosis of the renal vein was present in only 2 of the 20 cases of sarcoma of the kidney. Involvement of the perineural lymphatics was not encountered in any of these cases. It would appear that in this tumor and in the Wilms', neoplastic cells enter the vessels in the kidney and metastasize from this point.

Prognostic Significance of Tumor Thrombosis of the Renal Vein. In cases of carcinoma of the renal pelvis, the prognostic significance of tumor thrombosis of the renal vein or involvement of the lymphatics is greater than it is in cases of hypernephroma. The presence of tumor thrombosis of the renal vein or involvement of the perineural lymphatics or both apparently have little influence on the five year survival rate in the cases of Wilms' tumor. In cases of sarcoma of the kidney, the presence of thrombosis of the renal vein does not appear to be of prognostic significance.—*Mary Frances Vastine.*

Leary, Deborah C., and Peters, John P. Intravenous pyelograms in normal and abnormal pregnancies. *Am. J. Obst. & Gynec.*, Dec., 1943, *46*, 803–809.

Dilatation of the ureter in pregnancy has been repeatedly recognized in the past hundred years. The present study was undertaken in an attempt to determine whether toxemia of pregnancy and urinary tract infection in pregnancy would have any significant effect upon changes

in the urinary tract generally accepted as physiologic, viz., dilatation of the ureter. A group of 108 women in various stages of pregnancy and the puerperium were studied by means of intravenous pyelography. Diodrast was used throughout. In all, 113 pyelograms were taken. Five patients were examined twice.

Summary of Findings.

1. Twenty-three normal pregnant and puerperal women showed the changes usually associated with pregnancy. This ureteral dilatation (above the pelvic brim) does not ordinarily begin until the sixteenth week or later.

2. Post-partum studies in the normal group revealed regression to be rapid and in the majority of instances complete by the tenth day. No conclusive difference in relation to parity could be demonstrated.

3. Studies of 81 women whose pregnancy was complicated by toxemia or urinary tract infection revealed that in this group dilatation appeared as early as eight to twelve weeks and post-partum regression was far less frequently complete by ten days. When the infected group (26 patients) were assessed separately, these differences were exaggerated.

4. The reason for this delayed regression in toxemic women is not clear.

5. It is concluded that urinary tract infection and toxemia enhance the normal tendency to dilatation of the urinary tract in pregnancy and interfere with the usual prompt regression of these changes.—*Mary Frances Vastine.*

Chamberlin, George W., and Payne, Franklin L. Urinary tract changes with benign pelvic tumors. *Radiology*, Feb., 1944, *42*, 117–121.

The authors review the literature of the subject and discuss 96 cases of benign tumors of the pelvis in which they have studied the patients by excretory urography since 1937. Of these patients 66 (or 68.7 per cent) showed roentgen evidence of either displacement or obstruction of the ureters or both. There was obstruction in 47.9 per cent, displacement in 12.5 per cent and both in 8.7 per cent. There were urographic changes in 72.5 per cent of the patients with myomas, 43 per cent of those with ovarian cysts and 80 per cent of those with both cyst and myoma. This does not agree with the finding of Kretschmer and Kanter that changes are more frequent with ovarian cysts than with myomas. The size of the tumor has some effect on the degree of displacement or retention but the authors think the position of the tumor in relation to the pelvic ureter is more important than its size. Impacted or intraligamentous tumors caused the greatest changes.

The changes seen in these cases were qualitatively the same as those seen in pregnancy but were usually less pronounced. The changes in pregnancy are often attributed to hormones but these cases furnish evidence that the changes in pregnancy may be caused by pressure also. The urographic findings do not show the type of pelvic tumor. However, absence of function of one kidney is indicative of malignancy, while simple displacement or retention is more apt to result from benign tumor. All of the changes described here disappeared completely after operation.

The authors recommend excretory urography as a valuable preoperative study in cases of benign pelvic tumor.

In the discussion Dr. Gardner said he doubted the great value of urography in these cases. Too often the part of the ureter that is obstructed or displaced so that it might be injured during operation does not show in the urogram. There are better methods of demonstrating the exact location of the ureter, such as stereoscopic study of retrograde pyelograms or by leaving ureteral catheters in place so that they can be palpated during operation. He also said he believed the authors should have recorded the number of children the patients had for he believes there is always some residual atony of the ureter after delivery and multiparous women would therefore show greater ureteral dilatation with lesser degrees of pressure from tumor than nulliparous ones.

In closing, Dr. Chamberlin agreed with Dr. Gardner in regard to the question of residual atony of the ureter after pregnancy. He also said that in some cases of intraligamentous or incarcerated tumor the lower ureter cannot be demonstrated, but if it can it is of great value in operation.—*Audrey G. Morgan.*

ROENTGEN AND RADIUM THERAPY

Figi, Frederick A., New, Gordon B., and Dix, Christopher R. Radiodermatitis of the head and neck with discussion of its surgical treatment. *Surg., Gynec. & Obst.*, Sept., 1943, *77*, 284–294.

Chronic radiodermatitis is encountered fairly frequently. It occurs more often following

roentgen therapy than after radium treatment and the former is usually of greater seriousness because of the more extensive area involved. The tendency of irradiation to induce serious cutaneous changes is increased by rays from other sources, such as sunlight and ultraviolet and infra-red irradiation as well as chronic irritation of other types. The skin of certain persons is unduly sensitive to irradiation, either because of lack of normal pigment or because of an idiosyncrasy. Excessive reaction is observed particularly among those who have a fair or ruddy complexion, red hair or a thin, dry skin.

Radiodermatitis may occur either as an acute process reaching its height within a few weeks following exposure to the rays or as a chronic condition becoming manifest only after the lapse of months or years. The acute form is comparable to the three stages of burns except that the process progresses much more slowly. A dusky blue erythema is noted at the end of two weeks and either exuding or dry dermatitis after three weeks. A permanent brown discoloration due to increase of melanin and temporary or permanent loss of hair may follow this.

The necrosis, sloughing, and secondary infection of this stage often produce protracted disability, for healing occurs only after many weeks or months. The most destructive effect of the irradiation occurs in a central area and gradually decreases toward the periphery of the exposed surface. Months after the delayed healing the central portion of the area may break down again and the prolonged, painful sloughing and ulceration recur. Chronic radiodermatitis is usually preceded by the acute form, a latent period of from one to ten years generally intervening.

Pathology.

1. Complete loss of the appendages of the skin.
2. The replacement of normal collagen by a peculiar dense hyaline collagen.
3. Obliteration of the small vessels in the corium of the skin and subcutaneous tissues.
4. Necrosis and rarefaction in the corium usually associated with thrombosed regions of telangiectasia.
5. Reparative proliferation with hypertrophy of the epidermis.

Treatment. The acute stage is self-limiting unless excessive reaction is present and surgical treatment is contraindicated during this period. The chronic stage is progressive and there is a decided tendency for epithelioma to develop. Surgical removal is the only means of controlling the condition when secondary irradiation changes are pronounced. The surgical technique employed by the authors in the treatment of chronic radiodermatitis of the head and neck is given in detail.—*Mary Frances Vastine.*

Byars, Louis T. The "malignant" hemangioma. *Surg., Gynec. & Obst.*, Aug., 1943, 77, 193–198.

In infants, the arterial hemangioma must be given close consideration because of its tendency to spread, to deform or destroy features, to invade deep tissues and, in some instances, to produce death. This type may certainly be termed malignant. It is stated in medical literature that such birthmarks may disappear spontaneously. Except for the light reddish, splotchy areas over the back of the neck and between the brows frequently seen in infants, it is doubtful if such recession occurs.

Age of Treatment. Often the hemangioma appears in the first month of life. The proper time for treatment is as soon after appearance of the lesion as possible.

Choice of Treatment.

1. Portwine stain. This lesion involves the full thickness of the skin, is a reddish purple blotch, and grows only as the child grows. It is not sensitive to irradiation as a rule.

2. The venous angioma. This consists of large channels filled with venous blood; its growth is slow. Treatment is surgical. Occasionally, the interstitial use of radium is helpful.

3. The arterial angioma.
   a. Cautery destruction [illegible] should be considered [illegible] as possible.
   b. The carbon dioxide [illegible] should be used only for [illegible] ous lesions.
   c. Surface [illegible] radium rather than [illegible] author feels that the [illegible] plantation of [illegible] most valuable [illegible] the "malignant" [illegible] [illegible]

be employed. The total dosage may usually be calculated as one radon seed per cubic centimeter of tissue to be irradiated.

Complications.

1. Ulceration of the tumor. This appears spontaneously without trauma in many cases.
2. Secondary deformity.
3. Recurrence. Secondary treatment may be necessary if some portion of the tumor is not controlled at the original treatment.
4. Late surgical repairs.
5. Retention of gold seeds. There is no tissue reaction to the gold seeds which are contained in the tissues. Occasionally they may be visible under the skin and if so, they may be removed later.

Response to Treatment. The more rapidly growing hemangioma responds more readily than does the slower growing one. Ideally, progressive improvement should occur over a period of six months to a year in cases in which the minimum but adequate dosage has been used.—*Mary Frances Vastine.*

Warren, Shields, and Tompkins, Victor N. Significance of the extent of axillary metastases in carcinoma of the female breast. *Surg., Gynec. & Obst.*, March, 1943, *76*, 327–330.

The most important factor in predicting the survival of patients with carcinoma of the female breast after operative treatment has proved to be the presence or absence of metastases to lymph nodes in the axilla. It is generally agreed that the five year curability by surgery of operable cases in which the disease is limited to the breast is about 70 per cent, while that of the operable cases in which there are metastases to lymph nodes is about 23 per cent. So far it has been customary to note the presence or absence of lymph node metastases without determining the number of nodes involved. The 171 patients for this study were selected on the basis of available pathological material from those treated at the Pondville Hospital from 1927 to 1936 inclusive. The results of the study were:

1. *Effect of extent of axillary metastases.* The most significant finding is that curability on the basis of "five year cure" or longer periods of observation is inversely proportional to the extent of metastasis in the axilla. Fifty per cent cure in the group with least axillary involvement and 16 per cent cure in the group with most axillary involvement varies significantly from the average cure rate of 28 per cent for the whole group with axillary metastases. Seventy-seven per cent of those with all their lymph nodes involved were dead in two years whereas only 20 per cent of those with less than half their nodes involved died in a similar time.

2. *Effect of type of primary carcinoma.* It would seem that the type of tumor has less significance in prognosis than its extent. The breast tumors are not graded according to the method of Broders because the authors believe the personal equation in the process to be very great and the results have not been found to be significant.

3. *Recurrences in the operative scar.* For this series at least, recurrences in the operative scar increased with the extent of the disease in the axillary lymph nodes. It is reasonable to suppose that patients in whom metastases have occurred to axillary nodes should also have other metastases to the skin or the chest wall, thus increasing the likelihood of recurrence in the scar. The incidence of recurrences in operative scars suggests that they are of the nature of metastases or extensions rather than implants. —*Mary Frances Vastine.*

Mazer, Charles, and Greenberg, Rose. Low-dosage irradiation in the treatment of amenorrhea; analysis of an additional ninety-two cases. *Am. J. Obst. & Gynec.*, Nov., 1943, *46*, 648–654.

The authors summarize their article as follows:

1. A follow-up for nearly three years of 92 additional cases of amenorrhea, treated by means of low-dosage irradiation of the pituitary gland and ovaries, shows that 65 (72 per cent) of the patients have been menstruating normally.

2. The data gathered from a long-term follow-up of 165 cases, similarly treated and previously reported, show permanency of the cures and the safety of the procedure to both the patient and her offspring.

3. Of the 92 amenorrheic patients in the present group, 54 desired offspring but had not conceived despite the intensive use of organotherapy and other measures for several years. Twenty-eight (54 per cent) of the 54 barren women conceived and carried to term healthy

infants; 2 aborted during the first trimester of pregnancy. All of the 30 women have been menstruating normally since the termination of pregnancy.

4. A survey of the literature on low dosage irradiation of the pituitary gland and ovaries, as employed for the relief of amenorrhea, reveals no adverse effects either on the patients or their offspring.

5. Technique of irradiation: 135 kv., 5 ma., at a distance of 35 cm., with 0.25 mm. Cu and 1 mm. Al filtration through an anterior pelvic field. A dosage of 50 to 90 r, measured in air, is given and this is repeated three times at intervals of one week. The pituitary gland is treated with the same dosage at the same time through a field of 5 by 5 cm. just above and posterior to the mid-point of a line joining the outer canthus of the eye and the external auditory meatus.—*Mary Frances Vastine.*

MILLER, NORMAN F. Consideration of certain factors pertaining to the control of carcinoma of the cervix. *Am. J. Obst. & Gynec.*, Nov., 1943, *46*, 625–634.

Cancer destroys more lives than the combined toll from tuberculosis, diabetes, appendicitis, cirrhosis of the liver, alcoholism, and automobiles.

In 1931, the Gynecology Tumor Conference was inaugurated at Ann Arbor. Since this time, nearly 2,000 carcinomas of the female generative tract have been carefully evaluated and treated. Of this number, 65.8 per cent, or 1,235 were cervical cancers.

Quality of Treatment. A table which gives a panorama of five year survival rates since the turn of the century and in the hands of different investigators is enlightening. In some cases, surgery alone has been used, in others irradiation. In other instances a combination of the two has been employed. The highest survival rate is 58 per cent and the lowest 20 per cent. The author writes, "No one expects the impossible, but there is good reason to believe that therapy is disappointing."

Clinical Grouping—As used at the University of Michigan Hospital.

Group 1. Very early carcinoma of the cervix. This group includes the early suspicious, often unrecognizable clinically carcinomas of the cervix.

Group 2. Any clinically recognizable histologically proved carcinoma still confined entirely to the cervix.

Group 3. Carcinoma of the cervix with questionable parametrial thickening.

Group 4. All advanced carcinomas of the cervix.

Causes of Death. Patients with cervical cancer seldom die as a direct result of the neoplasm itself. In an analysis of the deaths among carcinoma patients to be reported by Dr. Russell deAlvarez, it was noted that in 66 per cent of the cervical cases death was the result of uremia, and/or impaired renal function caused by encroachment of the neoplasm or scar tissue upon the ureters.

Lay Education and Early Treatment. In 1933, the author reported an average time waste of 6.2 months prior to the patient's seeking medical advice. In 1941, R. M. Collins noted an average time waste of seven months between the onset of the first symptom and the first examination. When we consider the elaborate programs carried on by national, state and county organizations directed specifically toward the elimination of this time waste factor, the results of these efforts cannot be considered very encouraging.—*Mary Francis Vastine.*

MACDONALD, IAN, and BUDD, JOHN W. Osteogenic sarcoma; modified nomenclature and a review of 118 five year cures. *Surg., Gynec. & Obst.*, Oct., 1943, *77*, 413–421.

The authors present a review of 118 five year cures and 47 fatal results of osteogenic sarcoma of bone. They believe that the term "osteogenic sarcoma" is best used as a generic designation for the triad of connective tissue sarcomas primary in bone. This triad includes: (1) osteosarcomas (those sarcomas characterized by bone production), (2) fibrosarcomas, and (3) chondrosarcomas.

Summary of Findings.

1. True osteosarcoma is an almost uniformly fatal form of neoplasm.
2. Fibrosarcoma is a distinctly [illegible] form of osteogenic sarcoma.
3. Chondrosarcoma seems to occupy a [illegible] dian position occurring in approximately equal proportions among the [illegible] fatal cases.
4. Encapsulation of [illegible] favorable prognostic element. [illegible] of matrix has not been [illegible] prognostic value.

5. Natural selection determines curability to a greater degree than does early treatment for the delay in radical treatment is much greater in the cured than in the uncured neoplasms studied.
6. Biopsies were performed with more frequency in the cured cases than in the fatal cases.
7. The value of irradiation as a complementary curative agent in osteogenic sarcoma cannot be inferred from the data presented in this study. Actually, there is no significant statistical difference evident as a result of irradiation as approximately half of both the cured and uncured groups, in each of the three types of osteogenic sarcoma, were so treated. This does not imply that irradiation may not be of palliative benefit in many cases.—*Mary Frances Vastine.*

MISCELLANEOUS

Quimby, Edith H. Some aspects of the teaching of radiological physics. *Radiology*, Oct., 1943, *41*, 315–329.

The author points out the importance of close cooperation between radiologist and physicist in teaching and emphasizes some of the points in which the teaching of radiological physics is apt to be defective. The general subject of radiological physics includes (1) the purely physical part, covering generation of roentgen rays, radioactivity, interactions of radiation and matter; (2) measurement of quality and quantity, including calculation of dosage; (3) calibration and records, and (4) protection. The first part is quite adequately treated in books and papers but when it comes to the interaction of radiation and matter and its practical application, books are not so satisfactory. The blame for defective understanding of these matters is laid on the teacher. Too often not enough emphasis is placed on the practical application of various points. The student is required to learn definitions and rules but is not made to work out problems that show that he understands them. The teacher should make certain that the student understands the application of his teaching before he is passed. Keeping up with current literature on the subject is very important. The matters of determining dosage and of protection are as a rule quite inadequately understood by the student. A wealth of detail in regard to various physical points in radiology are given and illustrated with charts useful in teaching.—*Audrey G. Morgan.*

Cork, J. M. Some recent applications of nuclear physics. *Radiology*, Oct., 1943, *41*, 337–343.

It has been found that by suitable treatment practically every known element can be rendered radioactive. At present over 340 radioactive isotopes have been produced and identified. These radioactive elements may emit electrons, positrons and gamma rays and have half-lives that vary from a fraction of a second up to many years. An equation can be written for each reaction but only the total energy, not the number of atoms, on the right and left sides of the equation is equal.

It is evident that by using radioactive or tagged detectable elements the behavior of matter may be followed in any field of science. Some of the practical applications of this fact in astronomy, botany, chemistry, engineering, metallurgy, mineralogy, pharmacology, zoology and medicine are described. In medicine the radioactive elements may be used as tracers to study physiological processes. Also neutron radiation may be used in the treatment of malignant growths just as roentgen rays are used, and radioactive elements may be selectively absorbed to treat specific organs. For instance, radioactive strontium may be used in the treatment of bone tumors, radioactive iodine for thyroid disorders and radiophosphorus for leukemia and polycythemia. Neutron radiation has been found to be many times more powerful than roentgen radiation. If it is also found to have a greater differential effect on diseased and normal tissue it will be of enormous importance.

The addition of a single neutron of low energy to the nucleus of the uranium atom may cause it to split into two parts, releasing an energy of about 186 million electron volts. In the process more neutrons are formed so that if the process were controlled it might go on spontaneously. This is one of the most challenging facts in the scientific world today and its importance cannot be overestimated.—*Audrey G. Morgan.*

Lampe, Isadore, and Hodges, Fred Jenner. Differential tissue response to neutron and roentgen radiations. *Radiology*, Oct., 1943, *41*, 344–350.

As soon as it was discovered that the qualitative effect of neutron and roentgen radiation

was the same, effort was directed toward finding whether there was any difference in their selective action on different tissues with a view to determining whether neutron radiation could be used effectively in the treatment of cancer. In 1927 experiments made by Ferroux and Regaud showed that permanent sterilization of the rabbit's testes could not be brought about by a single dose of roentgen rays without severely damaging the skin of the scrotum. These experiments have been repeated and their findings verified. Fractionating of the dose, however, does produce a somewhat more differential action on the two kinds of tissue. The relative biological effects of fast neutron irradiation were tested under the same experimental conditions and it was found that within a restricted range of dosage there is sufficient selective activity on the part of the irradiation to bring about aspermatogenesis without seriously damaging the skin. Tables are given showing the effects of roentgen and neutron irradiation in these experiments. Though the difference in selective tissue action between the two kinds of radiation may be slight it tends to show that neutron radiation may become more useful than roentgen radiation in the treatment of malignant tumors.—*Audrey G. Morgan.*

Behrens, Charles F. Some considerations of wartime radiology in the Navy. *Radiology*, Sept., 1943, *41*, 284–287.

The author stresses the necessity of training in radiology for Navy men and urges the doctors in the Navy to make the most of their chances at training in this specialty. Almost all ships are now provided with some sort of roentgen unit and these may be damaged by careless handling when the ship is far from port and necessary parts cannot be obtained, or the physician or patient may be injured by gross ignorance of means of protection. The more leisurely programs used in the Navy in times of peace are now in abeyance for the duration of the war. Officers interested in radiology were formerly given a year or more in the roentgen department of one of the larger naval hospitals, followed by a year in a civilian medical center. This of course is not possible now; generally officers are given six months or less of training and then assigned to work, if possible as an assistant. But often it is necessary to put them in full charge and they must make the fullest use of their training and also be resourceful in meeting situations that arise for which they have had no direct training. Not only must they understand mass fluorography but they must be acquainted with the lesser details of the profession, such as processing, care and conservation of apparatus and material, general technique, the use of small units and related matters.—*Audrey G. Morgan.*

Myers, R. K. Federal regulations affecting allocation of x-ray equipment and supplies. *Radiology*, Sept., 1943, *41*, 288–290.

The author, who is chief of the X-Ray Section of the War Production Board, sets forth some of the regulations of that Board in regard to the allocation of x-ray apparatus and supplies. Unfortunately, many requests for such material must be refused. The best that can be done is to provide for minimum necessary requirements in civilian work. He urges civilian radiologists to bear in mind the tremendous demand for films for the Armed Forces and for industrial roentgenography, which has become a necessary and helpful factor in providing planes that can if necessary "fly on one wing," ships that hang together, armament that protects and ammunition that explodes. Bearing these things in mind the civilian radiologist should be as careful as possible in the use of films, tubes, etc. The War Production Board is there to help in every possible way and urges the cooperation of all radiologists.—*Audrey G. Morgan.*

Clark, L. H., and Jones, D. E. A. Some results of the photographic estimation of stray x radiation received by hospital x-ray personnel. *Brit. J. Radiol.*, June, 1943, *16*, 166–168.

A photographic method of determining the amount of radiation to which roentgen-ray workers are subjected is described. The workers carry dental films in their pockets, half of each film being subjected to the stray radiation in the room. Each member of the staff carries a cassette loaded with films for a week. The films are then standardized by submitting the unexposed parts to small doses of roentgen rays, the kilovoltage and filtration of which are known. In this way the amount of stray radiation to which the worker is subjected can be determined.

The results of over 2,000 films assessed over a five year period under average working conditions are presented and the results given in a graph and table. It was found that workers are rarely subjected to the daily tolerance dose of 0.2 r per working day.—*Audrey G. Morgan.*

Quimby, Edith H., and Pool, John. Protection in radiology. *Radiology*, Sept., 1943, *41*, 272.

This article is made up of photographic reproductions of the charts from an exhibit prepared by request for a "Graduate Fortnight" meeting at the New York Academy of Medicine. With some revisions and additions it was presented in the Scientific Exhibit of the American Medical Association at St. Louis in 1939.

There are charts showing the need for protection in radiology, the local and general effects of roentgen and radium irradiation, the effects following long-continued exposure without protection, methods of protecting the doctor, the technician and the neighbors, the effect of distance from the roentgen tube and radium source on the thickness of lead required for protection, the lead equivalence of building materials, tolerance doses, tests for protection and the recommendations of the International Commission regarding the welfare of full-time roentgen-ray and radium workers.—*Audrey G. Morgan.*

Meredith, W. J., and Stephenson, S. K. Some physical measurements with a 500 kV continuously evacuated x-ray tube. *Brit. J. Radiol.*, Aug., 1943, *16*, 239–241.

Measurements are reported which were made on a Metropolitan Vickers' Continuously Evacuated x-ray tube operating at 500 kv. constant potential. Absorption coefficients for aluminum, copper, tin, lead and mild steel (as used in the tube body) were obtained for 500 kv. radiations with only the fixed filtration of the tube. Effective wave length values obtained from these measurements are in good mutual agreement. Since it was desirable from the clinical point of view to use the shortest wave length consistent with a reasonable output rate a filter of 3 mm. tin, 0.5 mm. copper and 1 mm. aluminum was used in addition to the fixed filtration. A stepped aluminum filter was used to equalize the intensity at points from 0° vertically downward to 110°. Measurements taken after this filter was fitted show how successful its use was.

A table is given showing percentage depth doses for different depths and various field sizes. These were obtained from measurements in a pressdwood phantom at 50 cm. focus-skin distance using 500 kv. with the tin filter, with a half-value layer equal to 6.32 mm. copper. The values found are lower than those of Mayneord and Lamerton. A part of this decrease is due to the fact that closed applicators were used. Also the absorption coefficient for pressdwood is greater than that for water, which must be considered the standard material for depth dose measurements. These two points are being investigated and the depth dose values given in the table should not be considered final.—*Audrey G. Morgan.*

Wilson, C. W. Some data concerning the use of x-ray beams in direct (cross-firing) opposition. *Brit. J. Radiol.*, Aug., 1943, *16*, 247–249.

In deep roentgen therapy, for instance irradiation of the axilla or pelvis, a favorite technique is to use two identical beams cross-firing through opposite fields. This is one of the simplest methods of getting a large dose at the center point between the two fields, where the pathological focus is located, as compared with the skin dose. The dosage conditions provided by such a technique depend on various physical factors, such as the quality of the radiation, focus-skin distance, size of fields and distance between the opposite fields. A good method of determining the efficiency of an opposing field technique is to determine the ratio between the dose midway between the two fields and the dose at either surface. This gives a measure of the effective depth dose provided by the technique. Curves are given showing the effect on such effective depth doses of field area, focus-skin distance and quality of radiation.—*Audrey G. Morgan.*

Bush, F. The estimation of energy absorption during teleradium treatment. *Brit. J. Radiol.*, April, 1943, *16*, 109–112.

The value of the integral dose or energy absorption expressed in gramme-roentgens in a beam of radiation between two specified limits of dosage can be calculated with sufficient accuracy from the isodose diagram by determining the volumes between successive isodose surfaces. The sum of the products of each of these with its respective mean dosage rate gives the energy absorption. Some of the isodose surfaces will be cut by the body surface and to measure the integral dose the size of the parts of the interdose volumes that lie inside the body must be determined.

This article describes a method of determining the parts of the isodose volumes lying inside the body and measuring the energy absorption in any given case. It is illustrated by a diagram

of the pantograph and planimeter used in the measurements and by tables showing the results in 26 cases of teleradium treatment of cancer of the mouth, pharynx, larynx and glands of the neck. The accompanying changes in the lymphocyte counts are also given as a means of correlating energy absorption and physiological effect.—*Audrey G. Morgan.*

Ungar, E. M. A simplified method of studying volume dose distribution. *Brit. J. Radiol.*, Sept., 1943, *16*, 274–278.

In order to cause complete disappearance of a malignant tumor an adequate dose must be given to every part of the tumor. Sometimes recurrence of a tumor takes place because the dose has fallen off from the center toward the periphery of the growth and the periphery has been inadequately irradiated. In order to get a uniform and adequate dose to all parts of the tumor the lesion must be located and reconstructed and its volume and extent determined before proceeding to the problems of beam construction, volume dose distribution and beam direction. A detailed description is given, illustrated with diagrams and charts for giving axially symmetrical dose distribution to circular fields. The method can, however, be applied also to square or rectangular fields. The method makes use of tinted charts in which decrease of dose is represented by a fading density of the color. An accurate and complete diagram of dose distribution can be produced by adding the values of dose contours at points of intersection and then joining points which have the same dose. The method of making these tinted isodose charts is described, and the construction of isodose volume distribution described. At the Royal Cancer Hospital the use of the tinted isodose charts and charted beam sections for constructing volume dose distribution has made it possible as a matter of daily routine to fit a planned dose distribution to the shape and volume of a given tumor. A study of the charts and diagrams would be necessary for an application of the method.—*Audrey G. Morgan.*

Bush, F. The calculation of dosage rates from directional caliper measurements. *Brit. J. Radiol.*, July, 1943, *16*, 205–207.

Two directional calipers are in use for dosage rate measurements, model 1 designed by Green for use in roentgen therapy and model 2 for use with a teleradium unit. The author here describes an alternative nomographic method of measurement which can be applied to both models 1 and 2 and which requires no special apparatus. The geometrical theory on which the method is based and the construction of the nomogram are described and illustrated and the equations by which the calculations are made are given.—*Audrey G. Morgan.*

Cook, H. F. An investigation of the absorption of gamma rays in surface therapy applicators. *Brit. J. Radiol.*, April, 1943, *16*, 115–118.

In measuring dosage in radium therapy it has been customary to ignore absorption and scattering in applicator and patient. But it was found that the dosage given by applicators was lower than that calculated by the rules of Paterson and Parker and this was assumed to be due to absorption in the applicator. Experimental evidence of applicator absorption is given and methods shown for calculating this absorption and also tissue backscatter for applicators made of Columbia paste and Stent wax. Tables are given showing the details of the results. The mean apparent transmission of each of the typical applicators used indicated that applicator absorption was of the order of 10 per cent.—*Audrey G. Morgan.*

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CONTENTS

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ELECTROKYMOGRAPH FOR RECORDING HEART MOTION UTILIZING THE ROENTGENOSCOPE*

By GEORGE C. HENNY, M.S., M.D., *and* BERT R. BOONE, M.D.†

PHILADELPHIA, PENNSYLVANIA

THE recent application[8] of the 931-A multiplier phototube in the Morgan-Hodges phototimer has stimulated consideration of its use in the graphic recording of heart motion. Study of the electrical characteristics of the tube has indicated its suitability for this particular application and led to the construction of the apparatus, termed the electrokymograph, to be described in this paper.

The heart in its functioning as a circulatory pump undergoes a continuously repeated pulsatory motion. That each chamber of the heart and associated great vessels has its characteristic motion, and that this motion is characteristically altered in the presence of cardiovascular disease, has been well established.[3,11,14] The permanent graphic recording of this motion is a goal long desired and sought for, as the volume of literature indicates, but its attainment has been found to be difficult.

The visualization of the motions of the heart that became possible with the aid of roentgenoscopy suggested the possibility of applying the roentgen ray to some means of graphic recording of this motion. In 1926 Chamberlain and Dock[1] were able to make 15 roentgenograms of the heart in one second by means of the Ruggles roentgen cinematograph. By superimposing these roentgenograms in chronological order and measuring the change in position of points on the heart border, they obtained curves representing the progress of heart motion. The curves so obtained are of practically the same shape and possibly more accurate than those recorded subsequently by the roentgen kymograph. Chamberlain suggested to us the possible value of obtaining such records of heart border motion and stimulated us to investigate the problem. The roentgen kymograph shows on a single film a graphic record of the movements of the border of an organ in one plane. The original idea of the kymograph is credited to Sabat,[9] who did his work in 1911. Crane[2] in 1916 was the original American pioneer. Stumpf[13] devised the multiple slit kymograph in common use today. Hirsch,[5,6] Scott and Moore,[10,11,12] Johnson,[7] and Gillies and Kerr[4] have endeavored in recent years to popularize the method in this country.

While much good work has been accomplished by this method, roentgen kymography has not become established as a mandatory procedure in the examination of the

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heart. The explanation for this may possibly be found in a prevalent attitude that this is an interesting procedure that *can* be done but does not necessarily *need* to be done. That is to say, it is believed by many that the information thus obtained only corroborates information obtained by other more established methods, and does not as yet provide significantly new information. It seems that this is largely due to the analytic difficulties inherent in the unsharpness, the smallness, and the brevity of the recorded waves to be examined on the roentgen kymogram, together perhaps with the time-consuming nature of the analysis.

Given a record that suitably improves or corrects these particular limiting factors, it is believed there will be a substantial gain in the clinical information obtainable by the analysis of heart motion. The records obtained by means of the present electrokymograph overcome these difficulties, in producing a large, beam type, or electrocardiographic type tracing of a chosen point on the cardiac silhouette on bromide paper, of as many consecutive cardiac cycles as may be desired.

METHOD AND APPARATUS

The electrokymograph utilizes the roentgen-ray beam of the roentgenoscope. Its action may be outlined as follows (Fig. 1). Under the roentgenoscope the silhouette of the heart border may be seen to pulsate as the heart beats. If the roentgen-ray beam is restricted to a narrow rectangular area with its long dimension placed so as to be at right angles to the particular portion of the heart border under investigation, then the heart shadow will appear to move across this rectangle, covering more of it in the expansile stage of the heart cycle and less of it in the contractile stage. The average intensity of the roentgen rays at the fluorescent screen, over the whole rectangular area, thus varies in accordance with the motion of that portion of the heart border which is being scanned by the aperture. If the roentgen-ray intensity in respect to a time axis were recorded without distortion, the record would indicate the motion of this portion of the heart border.

Variation in roentgen-ray intensity could be measured and recorded by amplifying the current from an ionization chamber and applying this to a recording galvanometer. Such a method involves difficulties inherent in ionization chambers and stable high gain amplifiers. An easier solution of the problem became possible when the Radio Corporation of America made available the multiplier phototube. This tube is used by Morgan[3] in his exposure meter for roentgenography and the principle he so successfully developed is used by us. The 931-A multiplier phototube which we use contains a photosensitive cathode surface (with high sensitivity to blue-rich light) which emits electrons when illuminated. These photoelectrons are directed by an electrostatic field to a second surface called a dynode. Each electron impinging on the dynode surface knocks out several other electrons. These secondary electrons are then directed to a second dynode surface and they, in turn, knock out many times more new electrons. This multiplying process is repeated nine times, after which the greatly increased stream of electrons is collected by the anode and this constitutes the amplified current in the output circuit. The structure of the 931-A tube is very compact, being housed in a glass tube with over-all length of [illegible] cm. and a diameter of 3.3 cm. The current amplification in this tube alone is easily 100,000 for stable operation, and this may be increased to 200,000 by raising the voltage per stage to 150.

If a strip of fluorescent screen, Patterson type B, S in Fig. 2, is placed [illegible] the photosensitive area, M, the [illegible] 931-A tube [illegible] the fluorescent light [illegible] will illuminate the [illegible] Photoelectrons are [illegible] are greatly increased [illegible] [illegible]

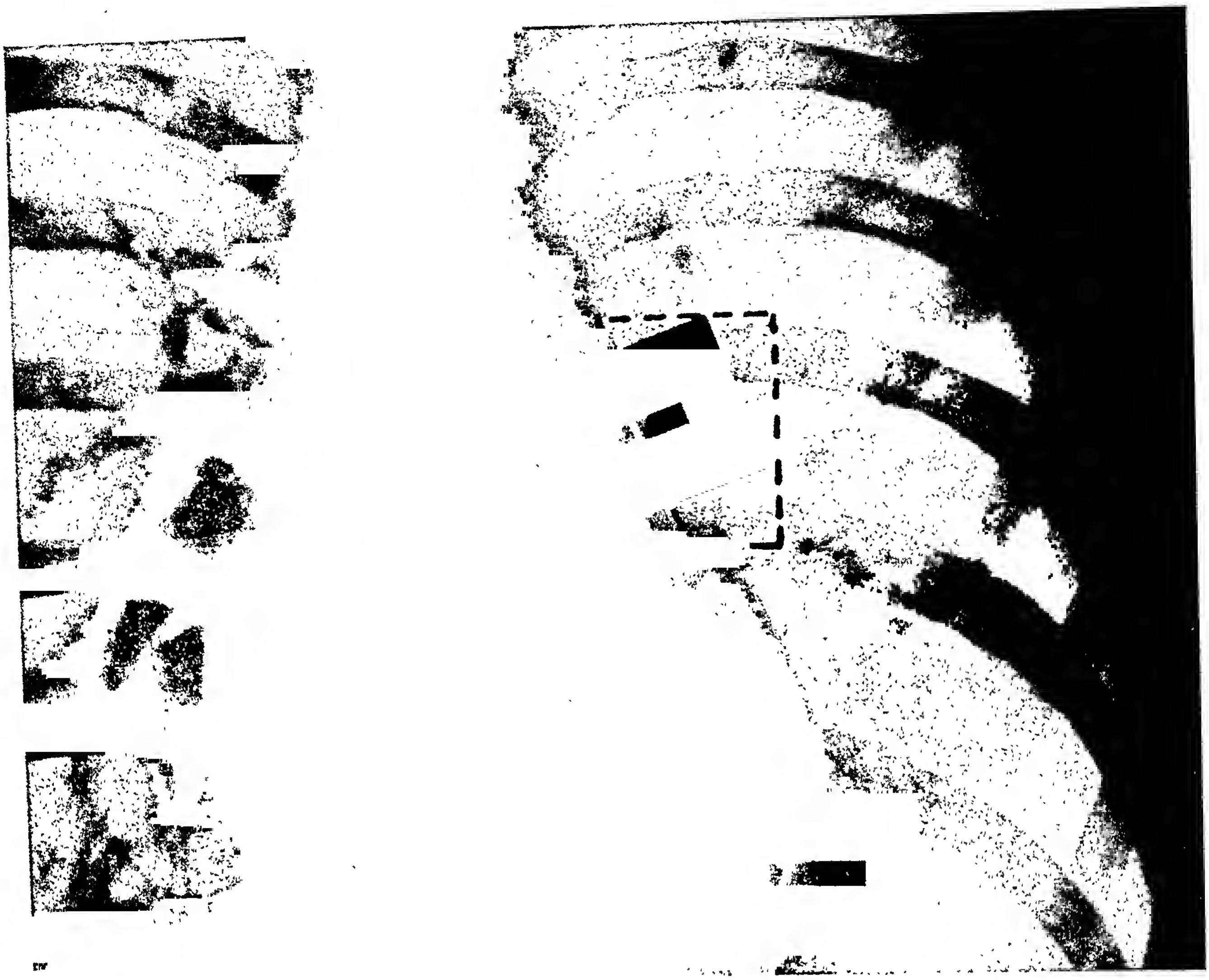

Fig. 1. Roentgenoscopic posteroanterior view of patient's chest. The diaphragm only (actual size) is illustrated on two points of the patient's cardiac silhouette. Note that the long axis of the diaphragm is placed in the direction of motion of the point of the heart border being investigated. As the heart goes into its contraction (dotted border) the shadow appears to move across the diaphragm. After the diaphragm system is properly aligned, the roentgen-ray beam is coned down by means of the roentgenoscope shutters to a small area as indicated by the dotted rectangle.

heart border moves inward (due to a contractile movement of the heart) more of this strip of fluorescent screen is further irradiated by the roentgen-ray beam. Thus the total light which is emitted is increased and the photosensitive surface within the 931-A tube responds by emitting a correspondingly increased number of electrons. Since the 931-A tube is operated in a range which is essentially free of distortion, the changes in output current are proportional to changes in position of the heart border over the narrow rectangular aperture defining the roentgen-ray beam. In practice the roentgen-ray beam is defined by a lead diaphragm system (D_2, Fig. 2) mounted directly in front of the 931-A pick-up device (and thus on the roentgenoscopist's side of the patient) and not by the roentgenoscope shutter system (Fig. 3). This has the advantage that it better enables the operator to orient himself on the exact portion of the heart silhouette which he wishes to investigate and also he can rotate the slot so that it is at right angles to the heart border motion, as indicated by the two positions of the diaphragm in Figure 1.

The dynodes of the 931-A tube are operated so that there is approximately a 100 volt drop from one to the next. This requires a direct current potential source of adjustable voltage output which is sta-

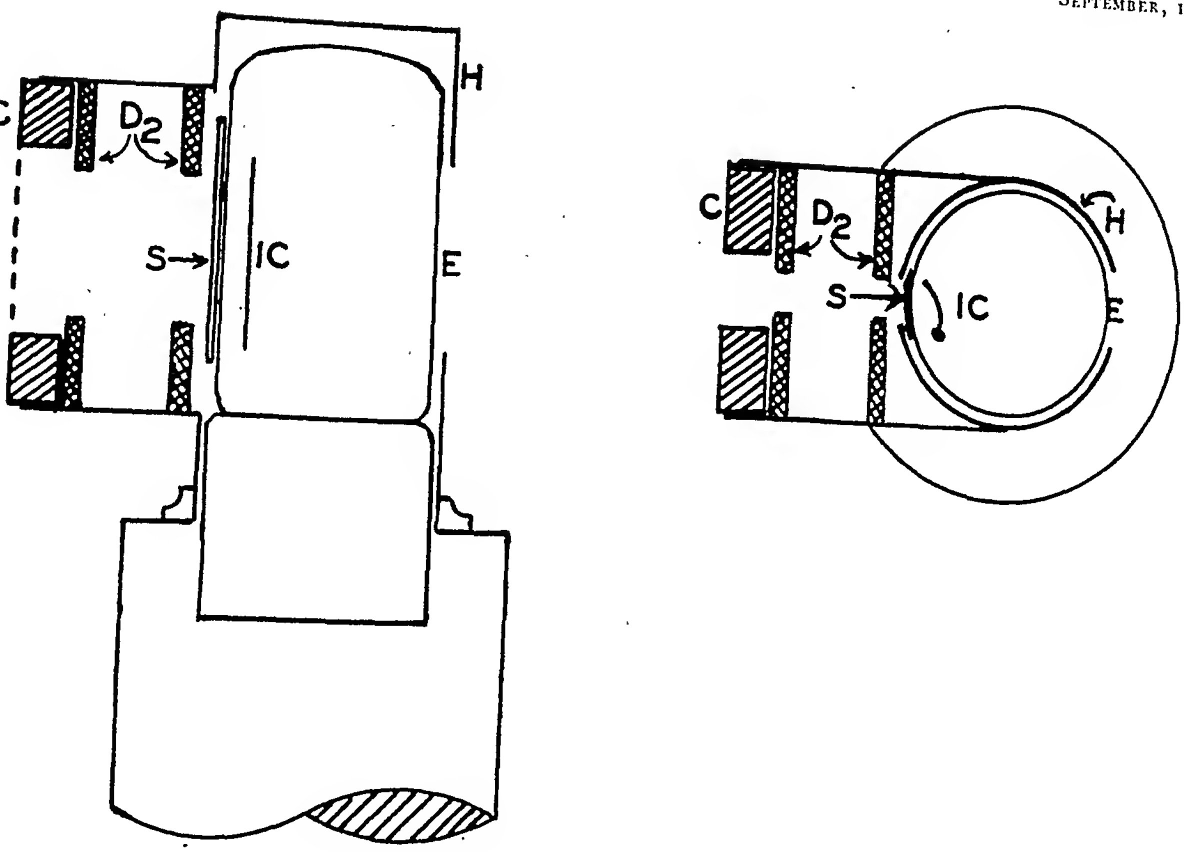

Fig. 2. Arrangement of the 931-A tube in its housing. The illuminated cathode, *IC*, of the tube faces the fluorescent screen, *S*. Black paper (not shown) is wrapped around the screen and tube before the copper hood, *H*, is placed over it so as to exclude all external light. The lead diaphragm system, D_2, with aperture 5 by 20 mm. restricts the roentgen-ray beam striking *S*. The 931-A tube is fairly transparent to roentgen rays so that part of the beam passes out of the window, *E*, and falls on the fluorescent screen. This facilitates proper aligning of the diaphragm. A bakelite facing, *C*, prevents metal from touching the patient's skin.

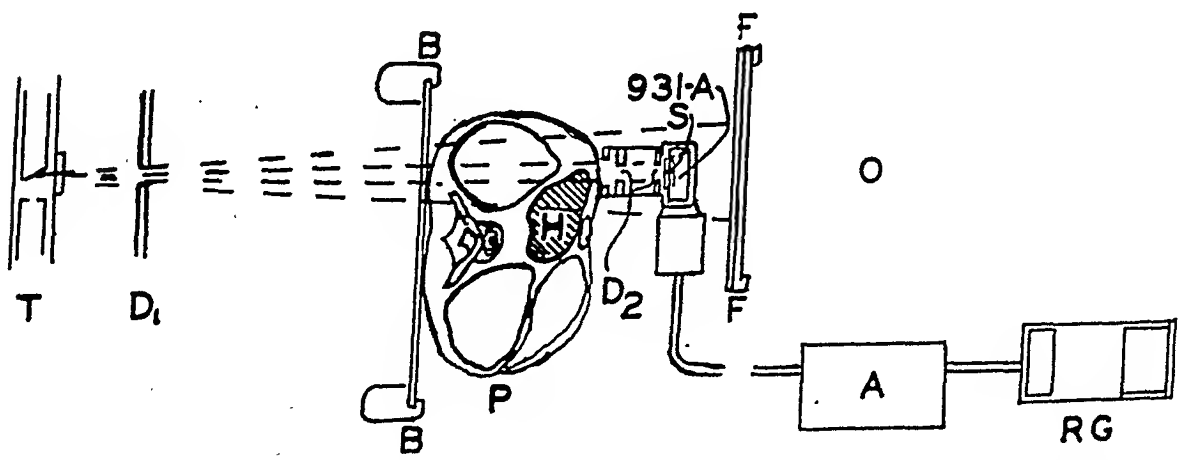

Fig. 3. Roentgenoscope, patient and 931-A pick-up device. A transverse section, *P*, of the patient with back to the roentgenoscope board, *B*, is shown. The roentgen-ray beam from the tube, *T*, is limited by the roentgenoscope shutter, D_1, and passes through the border of the heart, *H*, through the diaphragm, D_2, to the fluorescent screen, *S*. Light emitted by this screen falls on the photosensitive surface of the 931-A multiplier phototube. The emitted current is greatly amplified in this tube and further by amplifier, *A*, which then operates the recording galvanometer, *RG*. The observer at O aligns the 931-A diaphragm by means of the fluorescent screen, *F-F*.

bilized against incoming power line voltage changes. Such a power supply is shown in the right upper part of Figure 4. The filtered current from this power supply passes through a well insulated and shielded conductor to the voltage divider built right on the socket of the 931-A tube (T_1). By soldering to the prongs of the tube socket ten 0.1 megohm resistors, connected as shown, the high voltage is evenly distributed successively from dynode to dynode. A separate shielded conductor from the anode (*P*) of the 931-A tube carries the output current to the amplifier. The cable connections, voltage dividing resistors and tube socket are housed in a piece of bakelite tubing. After the 931-A tube is placed in its socket a hood (*H*, Fig. 2) made from copper tubing slips over the tube. On this hood is supported the lead-diaphragm system (D_2) which is properly aligned with the photosensitive surface of the tube. A piece of fluorescent screen about 1.0 by 2.5 cm. is placed against the glass envelope of the tube with the active side of the screen facing directly into the photosensitive surface of the 931-A tube. Black paper wound over this and around the tube not only holds the screen in place (which may be aided by strips of cellophane tape) but also keeps any external room light from reaching the photosensitive surface. The 931-A tube unit consisting of the lead-diaphragm system, fluorescent screen, light shield, 931-A tube and socket, voltage dividing resistors and cable connections is mounted on a support which is fastened by a set screw directly to the main fluorescent screen. It is mounted on the tube and patient side of this screen and in the middle of the screen so that when the lead diaphragm is properly aligned over the patient's heart border the shutters of the roentgenoscope can be closed down allow-

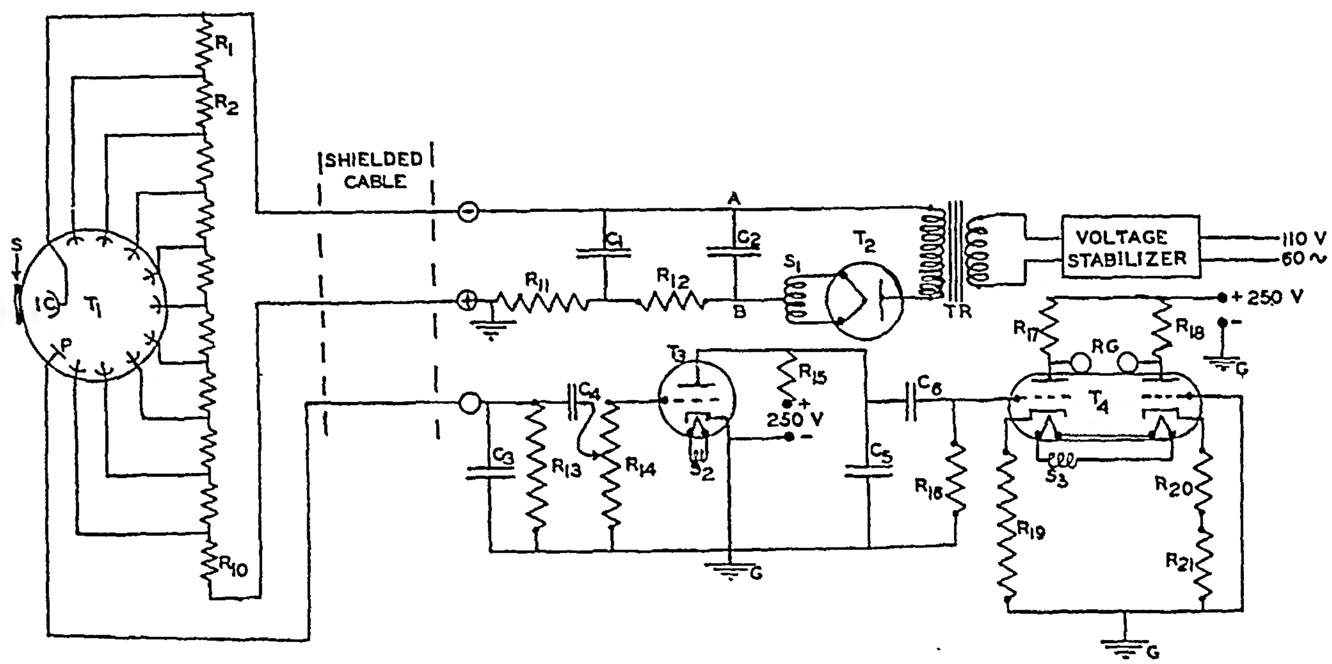

FIG. 4. Schematic diagram of the electrokymograph. *S*, fluorescent screen, sensitive surface facing *IC*; *IC*, illuminated cathode, photosensitive surface of 931-A; T_1, RCA 931-A multiplier phototube; *P*, collector plate or anode of T_1; R_1–R_{10}, 0.1 megohm ½ watt resistor network soldered to socket of T_1; R_{11}, 1 megohm potentiometer; R_{12}, 0.1 megohm 1 watt; R_{13}, 1 megohm ½ watt; R_{14}, 1 megohm volume control; R_{15}, 0.1 megohm 2 watts; R_{16}, 1 megohm ½ watt; R_{17} and R_{18}, 0.3 megohm 2 watts; R_{19}, 6,000 ohms 2 watts; R_{20}, 5,000 ohms 2 watts; R_{21}, 2,000 ohm potentiometer; T_2, 2×2 879 rectifier; T_3, 6F5; T_4, 6SN7; C_1 and C_2, 1 mfd. 1,500 V condensers; C_3, 0.03 mfd. paper; C_4, 1 mfd. paper; C_5, 0.25 mfd. paper; C_6, 1 mfd. paper; *TR*, 110 to 2,400 volt power transformer; S_1, S_2 and S_3, secondaries of filament transformer; *G*, ground or chassis connection; *RG*, connection to recording galvanometer. Voltage stabilizer, Sola constant voltage transformer 120 VA.

ing only a relatively small roentgen-ray beam to penetrate the patient (dotted rectangle, Fig. 1). This cuts down the exposure of the patient and the scattering of the roentgen rays by the patient's tissues. A small slot 0.8 by 2.5 cm. is cut through the back of the copper housing of the 931-A tube. This allows the roentgen-ray beam, after passing through the patient's heart border, the diaphragm system, the fluorescent screen and the 931-A tube, to pass through to the screen. The roentgenoscopist can thus sometimes (when the contrast is high) see the heart border motion through the diaphragm system on the fluorescent screen and thus greatly facilitate the proper positioning of the pick-up device over the patient's heart. A piece of bakelite (C) placed over the first lead diaphragm prevents metal from touching the patient as the unit is placed on the chest.

If the patient holds his breath for the short length of time during which the motion of the heart is being studied (for example, about 10 complete cycles), then complications from respiratory motion are eliminated. The output current from the 931-A tube is recorded by a resistance-coupled amplifier (one with a high time constant) in conjunction with a D'Arsonval galvanometer.

This system produces clear-cut records. The current output of the 931-A tube when used with a conventional roentgenoscope and a rather heavy patient is not quite sufficient to operate directly the string galvanometer of an electrocardiograph. A one-stage vacuum tube amplifier will doubtless take care of this deficiency. This will enable recordings to be made on standard equipment. Since this work has not yet been completed, only the amplifier and D'Arsonval galvanometer apparatus will be described.

A direct current amplifier which is stable in operation (without drift) over a long period of time requires rather complicated stabilizing circuits and considerable care in its operation. Fortunately the requirements of an amplifier to be used between the output of the 931-A tube and the D'Arsonval galvanometer are not so exacting. This is because it is a rather rapidly varying current that is being recorded and the record is made in a relatively short period of time. The type of amplifier used in the D'Arsonval galvanometer type electrocardiograph (that is with resistance condenser coupling between tubes) may be used. Care must be taken that the time constants ($R\times C$) are great enough for the heart motion being recorded, or distortion of the curve will result. The amplifier we have designed and used (Fig. 4) employs two stages, the second tube being a twin triode arranged to form a bridge circuit.[15] This has the advantages of stability and the balancing out of the direct current component of the plate circuit which might otherwise pass through the galvanometer. Once the balance has been obtained by adjusting R_{21} (Fig. 4), no further adjustment is required for a long period of time.

The DC power supply shown in the upper right hand part of Figure 4 provides a stabilized voltage for the 931-A tube. The potential at A-B is 1,400 volts. This is made adjustable by the rheostat R_{11} so that the voltage applied to voltage divider R_1–R_{10} may be varied. By gradually raising this voltage the amplification of T_1 is increased until maximum amplification is obtained without objectionable tube noise. The rheostat R_{11} may then be left in this position, without further adjustment. In practice the lead diaphragm of T_1 is properly aligned on the patient's heart border, the power supply is turned on, and after the tube filaments have warmed up, the gain control R_{14} is rotated from the minimum position upward until a satisfactory amplitude of motion is indicated by the recording galvanometer connected to RG. Care was taken in designing the amplifier to balance the values of the resistors and condensers in the networks so that high fidelity was obtained together with a fair degree of amplification. The power pack supplying the 250 volts to T_3 and T_4 is not shown. This is built according to conventional radio tech-

nique and utilizes a 300–0–300 volt power transformer with full wave rectification (80 tube) and a three-section condenser input filter. Three 16 mfd. electrolytic condensers and two 10 henry chokes are used with a 40,000 ohm bleeder resistor. The negative side is grounded.

The roentgen tube of a roentgenoscope is energized with a high voltage current that is pulsating. In full wave-rectification there will be 120 pulses of current per second to the tube and this results in 120 roentgen-ray pulses per second. These roentgen-ray pulses are faithfully reproduced by the 931-A tube and, unless suppressed, cause a very disturbing broadening and fuzziness of the recording curve which obliterates much of the fine detail otherwise present. For this reason low pass electrical filtration is incorporated in the amplifier (C_3, R_{13} and C_5, R_{15}, Fig. 4), with values of condensers and resistors chosen so that the low frequency components of the heart movement wave are passed with no appreciable distortion while the 120 cycle ripple is highly suppressed. This system is simple, and numerous tests on the fidelity of recording have shown that for practical purposes nothing is lost from the heart motion curve. Incidentally, an effort was made to smooth out the roentgen-ray ripple by connecting condensers in the high tension circuit of the roentgen tube. Using a condenser with an effective capacity of 0.25 mfd. across the high potential and 3 ma. through the roentgen tube (giving a time constant of many seconds), it could be shown that the voltage ripple was only a fraction of 1 per cent. Our tracings indicated that the roentgen-ray ripple was considerably more than this. This was traced to the alternating current which heated the filament of the roentgen tube. Since the filament cools momentarily between the current impulses, its electron emission simultaneously decreases with a consequent diminution in the roentgen-ray emission. This results in considerable roentgen-ray ripple even though the tube is supplied with a perfect constant potential. The ripple was readily picked up with our apparatus and its source was demonstrated when we could almost completely eliminate it by heating the filament with direct current from a battery. A single condenser discharge through the roentgen tube then gave a tracing entirely free of ripple. The routine use of a battery in the high tension line to heat the filament of the tube of the roentgenoscope is not practical, for the battery requires periodic charging and care, and the voltage tends to drop as it is used between chargings. The high voltage condenser is not an insurmountable obstacle but it requires space and is fairly expensive. Furthermore, unless very high capacities are used, some objectionable ripple will remain as we found with the 0.25 mfd. condenser. We therefore aimed at taking out the effect of the ripple in the amplifier, as mentioned above. Fortunately, this can be done without producing appreciable distortion in the recorded heart motion curve.

The recording galvanometer is of the permanent magnet D'Arsonval type such as is used in an electrocardiograph. The sensitivity is about 10 cm. per milliampere with a distance of 40 cm. from the galvanometer mirror to the film. The lighting system consists of a 15 CP 6 volt lamp in a housing with the usual lens-slit system to throw a narrow vertical beam of light from the galvanometer mirror on the opening of the recording camera. Above the opening of the camera is a white scale onto which part of the beam of light from the galvanometer falls, allowing direct observation of the beam from above, before and during recording. The bromide paper (6 cm. wide) in the camera is moved in the usual way with an electric motor. A speed of 50 mm. per second has been found to be about optimal for recording these waves which are spread out enough in respect to the horizontal timing axis to show excellent detail. As a time marker we are using an additional galvanometer similar to the one mentioned above, and employing the same light source. The timing galvanometer is actuated by impulses every one-tenth second

from a relaxation oscillator shown in Figure 5. This circuit is adjusted with resistors and condenser to have a natural frequency of oscillation of 10 cycles per second. Then by placing a wire connected to the 6.3 V filament secondary up along the surface of the neon bulb, the electrostatic field will trigger the tube at exact intervals of 6 cycles giving exactly one-tenth second impulses to the accuracy of regulation of the 60 cycle power lines. The absolute constancy of this triggering arrangement was demonstrated on a cathode-ray oscilloscope. The 210 volt DC supply is tapped off of the bleeder resistor of the amplifier power supply. The timing impulses, as shown on the bottom lines of Figure 6, are valuable for timing to 0.01 second the events of the heart motion curve.

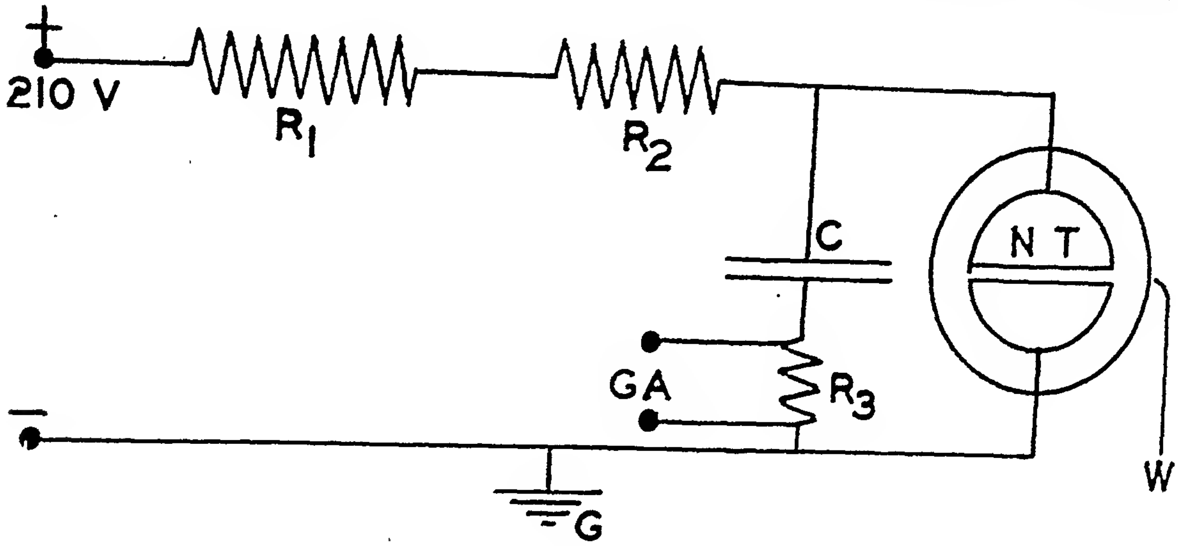

FIG. 5. Schematic diagram of relaxation oscillator which provides 0.1 second impulses to an additional recording galvanometer, thus producing a time marker on the tracing. R_1, 5 megohm 1 watt; R_2, 500,000 ohm rheostat for initial adjustment; R_3, 100 ohms; C, 0.1 mfd. paper condenser; NT, neon tube, 110 V, 2 watt semicircular electrodes; GA, connection to recording galvanometer; G, ground or chassis connection; W, wire connected to 6.3 V filament winding (S_2, Fig. 4) and placed against the neon tube.

Two curves of the motions of two points along the heart border have not been recorded simultaneously. This would necessitate doubling the apparatus, but more serious still would be the difficulty of aligning the 931-A pick-up devices on the two points. Inspiratory changes or slight movement of the patient could get one or both of the tubes out of line. Furthermore, we have found that it is not necessary to record the various points of the heart border simultaneously because we have been able, with a high degree of accuracy, to line the curves up in respect to the time axis. This is accomplished by recording simultaneously along with each heart motion curve a pulse tracing from the right carotid artery. The pulse tracing is quite characteristic for each individual and remains essentially constant in shape for the short period of time required to make the heart border tracings. There are well defined dips or peaks on the pulse tracing which may be marked. Then by placing on a vertical line the same point of the carotid pulse tracing of each heart border motion curve, the time axes will be very accurately aligned and the relative motion of each point of the heart border can be coordinated by considering points on a vertical line. Time delay of equivalent movement for each point or paradoxical motion can be demonstrated. The carotid pulse is recorded by means of a very simple device. A small bakelite cup 3 cm. in diameter is held in place over the right carotid artery by means of a light wooden clamp. The clamp fits the neck and slides with a gripping ac-

tion so that as the cup is placed on the carotid artery and the movable part of the clamp is pushed against the other side of the neck it stays in place when the hands are removed. The pulsations in the neck are easily palpated so the cup can be put in the

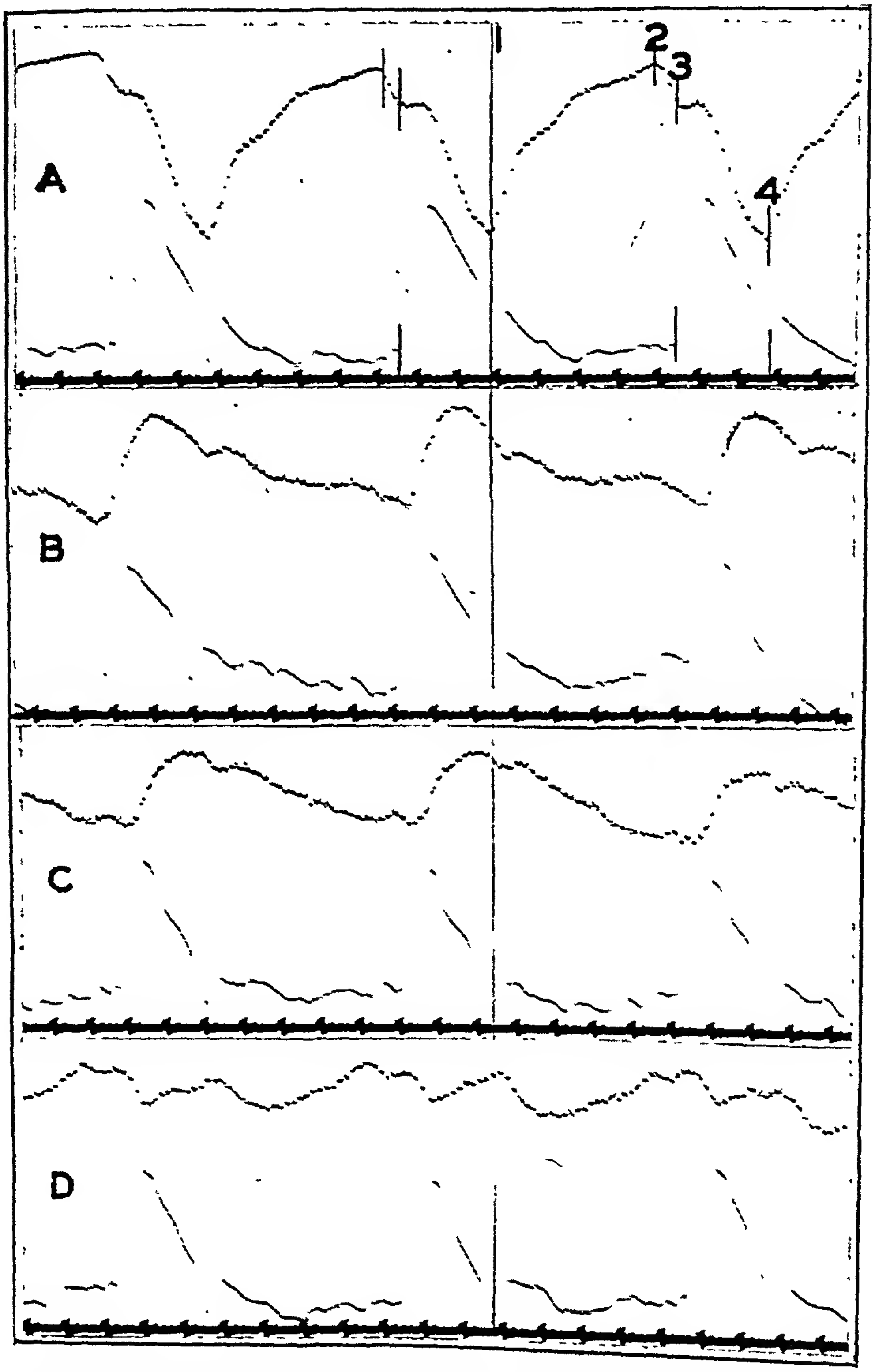

Fig. 6. This figure shows sample records of heart border motion. In each of the above records, the lower curve is from the right carotid artery. Line 1 passes through the incisura of each pulse record thereby placing the events of each record on a common time relationship for that particular cycle. Record *A* is recorded from the left ventricle, *B* from the pulmonary artery, *C* from the aortic knob, and *D* from the right auricle. In record *A*, line 1 denotes the end of systole and onset of diastole; line 2 the onset of systole and closure of the mitral valve; line 3 the opening of the aortic valve and beginning ejection; and line 4 the end of systole. The timing line at the base of each record indicates 0.10 second intervals.

proper place in a few seconds and it does not bother the patient. A fairly thick walled rubber tube with inside diameter of about 4 mm. is connected to this pick-up cup and carries the air borne impulses to a rubber diaphragm segment capsule and mirror mounted in front of the camera. Light from the same source used for the galvanometer is reflected from this cylindrically concave mirror to form a narrow band at the camera and is thus recorded as a well defined wave.

This pulse recording system is not completely air tight as would be necessary were quantitative volumetric curves desired, but rather has a slight intentional air leak which does not appreciably alter the configuration of the curve. This allows the light beam to return to its base line in approximately ten seconds if the rest of the system should be completely air tight after being adjusted on the patient. In our case the air leak occurs in the segment capsule and is adjusted by increasing or decreasing the turns of the rubber band holding the rubber diaphragm in position. This arrangement is similar to that used by Wiggers and Dean.[16]

APPLICATION

The apparatus that has been described was designed and constructed specifically for graphic recording of heart border motion. Other applications will doubtless suggest themselves to investigators interested in the motion of organs within the body.

The principal requirements for recording by such apparatus are (1) that the organ be visualized on the fluorescent screen; (2) that the amplitude of motion be less than 25 mm. (the length of the photosensitive surface of the 931-A tube); (3) that the density of the organ be of sufficient contrast to adjacent tissues, or can be made so by injection or ingestion of opaque materials, and (4) that the frequency of the motion be within the characteristics of the amplifier and the recording system. Regarding the organ density, experience has shown that the greater and sharper the contrast of the borders under motion, the better the recording; when the density of the moving organ approximates [illegible] that of the adjacent tissues, the ability to record is correspondingly poor. It is also possible to record rapid changes in density of an organ due to an inflow of air or blood: for example, the parenchymal portion of the lung.

The heart is an organ having motion that fulfills these requirements particularly well. Furthermore, the thorax can usually be positioned roentgenographically so that the borders of each chamber of the heart can be silhouetted and hence its motions recorded. Also, the borders of the aorta and pulmonary artery can similarly be silhouetted and their motions recorded.

A considerable amount of research has been done on heart motions by means of the roentgen kymograph, so it is desirable to compare that method with the electrokymographic method being presented. With the roentgen kymograph (1) a number of points of motion on the heart border are recorded simultaneously on one film, (2) only one, rarely two cardiac cycles are recorded on each point; (3) the amplitude of motion on the record is small, usually 4 to 8 mm.; (4) unsharpness on the record frequently impairs wave analysis, and (5) only the horizontal component of motion is recorded. In comparison, the electrokymograph (1) records a single point [illegible] at one time; (2) records [illegible] cardiac cycles of this point [illegible] sired; (3) [illegible] ord up to 25 mm. [illegible] justments; (4) records [illegible] record which are sharp, [illegible] read, and [illegible] a point and not [illegible] parent.

[illegible]

[illegible]

phototube and its resistance network is guided by the roentgenoscopist to a position over the heart border. The diaphragm on the phototube is placed directly against the chest wall and is aligned so that the center of the aperture is on the point of the cardiac silhouette being studied. The long axis of the diaphragm coincides with the radial motion of the heart border. Thus if the point is moving horizontally, the lengthwise axis of the aperture will be horizontal; if the direction of movement is 20° above horizontal, the lengthwise axis of the aperture will be inclined 20° to coincide. Thus the "radial motion" of the point is obtained (Fig. 1). The aperture is then adjusted along this radial line until the two extremes of motion (systole and diastole) are within the confines of the aperture. The amplifier gain is now adjusted to a point where the excursion of the photographic beam is about 15 to 20 mm. Too great an amplifier gain may roughen the recording beam unnecessarily. The patient stops breathing on request and the camera is started, and usually ten heart beats counted; the camera is then stopped and the patient requested to resume normal breathing. The patient may be in recumbent or upright position as the conditions of examination require.

To facilitate analyzing the records a recording of the right carotid pulse is made simultaneously on each patient and registers on the film below the heart motion tracing. Thus as the motion of a series of different points is recorded, the carotid pulse tracing provides reference points for correlation purposes.

INTERPRETATION OF RECORDS

Before any interpretation of the records obtained may be considered, explanation of the movements of the light beam on the recording film is necessary. As the light beam moves to and fro in accordance with the movements of the heart border, wave forms are produced on the film. The waves are seen to have asymmetrical upward and downward limbs (Fig. 6). The upward moving limbs represent expansile or filling phenomena, while the downward moving limbs represent contractile or emptying phenomena. The steeper the slope of a wave limb, the more rapid the action or movement, and the less steep the slope, the slower the action. Changes of slope upon a limb represent changes in speed of action, and notches or serrations represent smaller superimposed changes of action. When the tracing runs parallel to the moving axis of the film, the state of no motion is indicated. The timing spots at the bottom are 0.10 sec., and film speed is approximately 50 mm/sec. The time axis is from left to right.

Figure 6 illustrates the records of motion obtained from various points on the heart border by means of this apparatus. The motions represented are those of the left ventricular border, the pulmonary artery, the aortic knob, and the right auricular border. The posteroanterior position was used with patient in upright position. The downward peak of the incisura wave of the carotid pulse has been utilized as a common time reference point. Thus, all records may be lined up, one above the other, so that a vertical line passing through all of them passes through the incisura of the carotid wave on each. Events on the different records falling on any given vertical line are thus occurring at the same time.

The wave forms for each of the border areas of the heart are found to be characteristic of that particular area, and to resemble closely the respective volumetric wave forms found in the physiology texts. The ventricular (Fig. 6*A*) waves follow very closely, but not exactly, the ventricular volume curves. Beginning with the incisura line, which indicates closure of the semilunar valves (end of systole and beginning diastole) the rising wave limb of ventricular motion is bent, the steeper portion representing rapid diastolic filling and the less steep portion representing the phase of slow diastolic filling. The peak of the wave is related to beginning systole, and the closure of the mitral valve. The opening

of the aortic valve is related to the notch at the beginning of the down limb. The steep downward limb represents ventricular systole, which terminates with the closure of the semilunar valves (the incisura of the pulse wave).

The pulmonary artery motion (Fig. *6B*) presents a wave form with a sharply rising limb, a rounded crest, and a slowly descending limb, on which is a notch related to the closure of the semilunar valves. The sharply ascending limb is related to the ejection phase of ventricular systole. The beginning point of the wave marks the opening of the pulmonary valves.

The aortic knob (Fig. *6C*) presents a wave form very similar to the pulmonary artery but occurring slightly later in time, thus helping to differentiate it from the pulmonary artery wave.

The right auricular wave (Fig. *6D*) is the most difficult to describe, since a pure auricular wave motion is rarely recorded. The adjacent right ventricle imposes its motion upon it, sometimes completely masking true auricular motion. Lack of a characteristic wave form is perhaps the dominant feature of this area. However, with careful time measurements and cross correlations the time of auricular systole can usually be identified, with the other waves seen to be related to the events of the right ventricle. The lower the point chosen on the right auricular border the more prominent becomes the right ventricular component, and in some cases a pure ventricular wave is recorded on the heart border in the vicinity of the cardio-hepatic angle. This substantiates previous mention that the right ventricle may contribute to the make-up of the right heart border in the anteroposterior silhouette.

The record of the electrokymograph and its general meaning have been described in the briefest manner. The detailed information regarding each chamber of the heart will be made the subject of subsequent papers. It is sufficient to indicate that the normal curve of any chamber is dependent upon the normal action of the myocardium and the normal opening and closing of the valves related to that chamber. With alterations in the character of the myocardium, or defects of the valves, there will be corresponding alterations in the limbs of the curves.

One cardiac condition, aortic insufficiency, will be mentioned briefly to illustrate the potentialities of electrokymography. Normally, the left ventricle is a completely closed chamber during two phases of its cycle, i.e., the isometric contraction phase and the isometric relaxation phase. During both these phases the aortic and mitral valves are closed. Now with an insufficient aortic valve exhibiting a to and fro murmur, the left ventricle is no longer a closed chamber during any phase of its cycle. The ventricular record of motion will therefore exhibit corresponding alterations on the filling and emptying limbs of the curve.

In a similar manner, electrokymography should prove useful in cases of aortic stenosis, mitral disease, myocardial infarction, and other cardiovascular diseases.

SUMMARY

1. An electrokymograph utilizing the roentgenoscope is described. The apparatus is for the recording of heart border motion.

2. The technical aspects of its principles and construction, together with its operation, are described in detail.

3. Records of motion from various parts of the heart border are presented and discussed.

REFERENCES

1. [illegible]

2. [illegible]

3. [illegible]

5. Hirsch, I. S. Recording of cardiac movements and sounds by the roentgen ray (kymophonoroentgenography). *Radiology*, 1934, *22*, 403–422.
6. Hirsch, I. S. Application of kymoroentgenography to the diagnosis of cardiac disease. *Radiology*, 1934, *23*, 720–737.
7. Johnson, S. E. Roentgenkymograph as new aid in diagnosis of adhesive pericarditis. *Surg., Gynec. & Obst.*, 1935, *61*, 169–174.
8. Morgan, R. H. Photoelectric timing mechanism for automatic control of roentgenographic exposure. Am. J. Roentgenol. & Rad. Therapy, 1942, *48*, 220–228.
9. Sabat, B. Ueber ein Verfahren der roentgenographischen Darstellung der Bewegungen des Zwerchfells des Herzens der Aorta. *Lwow. tygodn. lek.*, July, 1911, No. 28.
10. Scott, W. G., and Moore, S. Construction of roentgenkymographs and kymoscopes. *Radiology*, 1936, *26*, 622–629.
11. Scott, W. G., and Moore, S. Roentgenkymography; its clinical and physiological value in study of heart disease. *Ann. Int. Med.*, 1936, *10*, 306–329.
12. Scott, W. G., Moore, S., and McCordock, H. A. Roentgen kymographic studies of cardiac conditions. *Radiology*, 1937, *28*, 196–210.
13. Stumpf, P. Das röntgenographische Bewegungsbild und seine Anwendung (Flächenkymographie und Kymoskopie). G. Thieme, Leipzig, 1931.
14. Sussman, M. L., Dack, S., and Master, A. M. Roentgenkymogram in myocardial infarction. 1. Abnormalities in left ventricular contraction. *Am. Heart J.*, 1940, *19*, 453–463.
15. Thurston, J. N. An A-C operated vacuum tube voltmeter. *Electronics*, 1943, *16*, 102.
16. Wiggers, C. J., and Dean, A. L. Principles and methods of direct registration. *Am. J. M. Sc.*, 1917, *153*, 666.

THE ENTRANCE OF PANTOPAQUE INTO THE VENOUS SYSTEM DURING MYELOGRAPHY

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MYELOGRAPHY, using opaque oil, has become an important and accurate diagnostic procedure. A valuable contribution was made when pantopaque was introduced for this purpose.[10,11]

Pantopaque (ethyl iodophenylundecylate) contains 30.5 per cent iodine and because of its admirable physical and chemical properties (which will not be discussed here) has proved highly satisfactory for diagnostic purposes and, in our experience, has given rise to no complications in the patients on whom it was used.

The control material was not, however, designed or intended for intravenous use.

It is the purpose of this paper to report a case in which 3 cc. of pantopaque inadvertently entered the venous system of a patient without serious consequences. To my knowledge, this is a unique occurrence. The spot roentgenogram (Fig. 1) is of considerable interest as a curiosity.

CASE REPORT

The patient, soldier, aged twenty-five, was admitted to Walter Reed General Hospital because of persistent pain in the lower part of the back. The pain was not very severe, remained in the midline, and was relieved by restriction of activity. There were no significant neurological or orthopedic findings except limited mobility in the presence of pain. There were no significant laboratory findings. Anteroposterior, lateral and oblique roentgenograms of the lumbosacral spine revealed no abnormalities.

Clinically, the diagnosis was not clear cut, and it was decided to make a myelogram to rule out intradural or intervertebral disc disease before final disposition of the patient.

On July 13, 1943, the following procedure was carried out in the roentgenoscopic room of the Roentgen Department.

The patient was placed on the table in prone position with the head of the table elevated 30 degrees, and a pillow was placed under the pelvis.

3:00 P.M.—A needle was inserted at the fifth lumbar interspace and clear spinal fluid was withdrawn from the needle.

3:01 P.M.—3 cc. of pantopaque (1 ampule) was injected without unusual manifestations. The needle was covered with sterile drapes and allowed to remain in place. The head end of the table was kept elevated 30 degrees. The pillow was removed from beneath the pelvis and lower abdomen. The patient lay prone upon the roentgenoscopic table. The room was darkened and the table brought to the horizontal position. The fluorescent screen was swung into position and a film placed in the spot film device.

3:05 P.M.—The roentgenoscopist (the author), who was fully "dark adapted," saw the pool of pantopaque about the needle point at the level of the fourth and fifth lumbar vertebrae. No abnormalities were seen.

3:06 P.M.—In order to demonstrate that the oil was lying free in the subarachnoid space, the patient was asked to cough.* As the patient coughed, I saw a marked and bizarre change in the pantopaque column. It appeared to extend in all directions like a star-burst. The original subarachnoid oil column shrank rapidly and branching, slender finger-like columns of oil were seen extending to the right, the left, caudad and cephalad from it. Within fifteen seconds no oil could be seen in the subarachnoid space and a broad oil column was seen forming to the right of the lumbar spine. It was at once realized that the oil had entered the venous system.

3:06½ P.M.—A spot roentgenogram was taken using a stationary grid (Fig. 1).

The patient coughed and complained of "tightness in his chest," but continued to breathe and cooperate well.

Other spot roentgenograms were taken as rapidly as the cassettes could be slipped into and out of the tunnel. None of these showed opaque oil.

* This is a simple but helpful maneuver which I have [illegible] this examination many times. When the [illegible] space, the column splashes and migrates [illegible] has been injected subdurally it does not [illegible]

3:08 P.M.—Roentgenoscopy of the entire spine, skull, chest, heart and abdomen revealed no opaque oil.

3:09 P.M.—Without further aspiration, the needle was removed, the patient transferred to a stretcher, and roentgenograms were taken of spine, abdomen and chest. At this time the patient was feeling better, but showed a rapid regular pulse (100) and appeared pale and shaken.

The films were developed immediately but showed no opaque oil or evidence of cardiac or pulmonary abnormality. No opacity was seen in the renal or bladder regions.

Chest and abdominal roentgenograms taken four hours later (7:00 P.M.) were also negative. Chest roentgenograms taken daily for a week, and weekly for two months after the episode showed no abnormalities, and no change since the original roentgenogram.

A twenty-four hour urine specimen July 13–14, 1943, showed 56.65 mg. of iodine in 1,100 cc. (method of White and Rolf).[15]

For the next two days the patient was kept in bed and showed a low grade elevation of temperature to 99.4°F. He developed a leukocytosis up to 13,000 with 6 per cent eosinophils. This subsided by the third day and he was allowed to be up. He had no complaints which could be attributed to the procedure.

Two weeks later the same method revealed merely a "trace" of iodine in the urine.

The feces were not tested for iodine.

COMMENT

Other opaque substances have been inadvertently introduced into veins. This is not uncommon in retrograde pyelography (pyelovenous backflow). It has occurred several times with lipiodol in the course of uterosalpingography.[7,14]

Pantopaque is not intended for intravenous use and no report is known of its entrance into the venous system. No other case is known in which any opaque substance has entered the venous system during or as the result of myelography. The incident is therefore viewed as a curiosity rather than a complication to be anticipated or feared.

Strain[12] has slowly administered 8 cc. of pantopaque intravenously to dogs weighing 15–20 kg. without serious results. Rapid injection resulted in a fatality. When the oil was emulsified, dogs tolerated as much as 20 cc. intravenously.

The manner in which pantopaque is broken down, hydrolyzed, and excreted is not understood and is still being studied. We have evidence in this case that a measurable amount of iodine was excreted in the urine in the first twenty-four hours. A "trace" was found in the urine two weeks later.

FIG. 1. Spot roentgenogram of lumbar region taken thirty seconds after coughing and five and one-half minutes after injection. The opacified veins are presumably the intervertebral, lateral sacral, and lumbar veins. The inferior vena cava lies to the right of the spine. No oil remains in the subarachnoid space about the spinal puncture needle.

DISCUSSION

Certain deductions appear to be justified and are made in order to offer at least a possible explanation of this unusual incident.

1. The needle must have entered the subarachnoid space since clear (not bloody) spinal fluid was withdrawn.

2. The pantopaque was deposited in the neural canal; it was seen there by the roentgenoscopist, and appeared to be in the subarachnoid space.

3. The oil did not immediately enter the veins. It was seen roentgenoscopically within the spine four minutes after injection.

Instantly following the cough the oil was observed to leave the canal by means of multiple curvilinear pathways (veins). The exit of the oil was so rapid that in fifteen seconds the initial collection had disappeared from the spine; in thirty seconds it was shown in the inferior vena cava, and in several tributary veins (Fig. 1); and in one minute it had completely disappeared.

4. From the above it appears that the cough was the precipitating factor. It has been shown that coughing, sneezing, and straining cause a tremendous rise in the cerebrospinal fluid pressure.[9] This pressure is many times that in the abdominal veins (patient lying prone) and we may assume that the oil was forced into one or more veins by the cough.

To explain the entrance into the veins one must postulate a defect in the venous wall.

(a) This was possibly caused by the initial insertion of the needle at 3:00 P.M. The absence of blood in the spinal fluid is difficult to explain in this case.

(b) Possibly the wall of the vein was torn or perforated by contact with the needle point in the act of coughing at 3:06 P.M. This hypothesis is better suited to the facts and timetable.

(c) Abnormal vessels in the cord or meninges might offer an explanation. Large vessels are found in meningioma, particularly the meningothelial type;[2] hemangioma;[4,6] or venous angioma (racemose type).[3]

The presence of the opaque oil in the inferior vena cava is not surprising, as all the complicated veins and plexuses in this region drain either directly or indirectly into the cava.*

SUBSEQUENT STUDY

A spinal puncture was not done to study the fluid for blood or iodine following the above incident.

Because the suggestion of vascular tumor was made by the roentgenologist, a second myelogram was made (July 30, 1944). The needle was inserted at the second lumbar interspace and the examination was carried out without mishap. Roentgenoscopy and roentgenography revealed no variation from the normal.

SUMMARY

During the course of a myelographic examination, 3 cc. of pantopaque entered the venous system and rapidly ascended the inferior vena cava.

There was no objective evidence of oil embolus, and the toxic manifestations of the iodinated substance were very slight.

This is a unique occurrence, the actual mechanism and cause for which remains undetermined.

REFERENCES

1. Batson, O. V. Function of vertebral veins and their role in spread of metastases. *Ann. Surg.*, 1940, *112*, 138–149.

2. Brown, M. H. Intraspinal meningiomas; clinical and pathologic study. *Arch. Neurol. & Psychiat.*, 1942, *47*, 271–292.

* *Anatomy of the Veins in the Lower Lumbar Region*[1,4,11] The spinal medulla and meninges contain a network of veins which are largest in caliber in the lumbar region. This network drains into the intervertebral veins and into the internal vertebral venous plexuses.

There are two of these rich venous plexuses within the spinal canal: (1) the posterior internal plexus which receives the basivertebral veins from the bodies; (2) the anterior internal plexus which receives blood from the medulla and meninges.

Both internal plexuses which lie between the dura and the bone are linked by "venous rings," the retia venosa vertebrarum. Both plexuses communicate by means of large channels with the intervertebral veins which emerge (along with the nerves) through the intervertebral foramina and empty into the lumbar and lateral sacral veins.

The lumbar veins, usually four pairs, empty directly into the inferior vena cava (above, and to the right of the fifth lumbar).

The lateral sacral veins (bilateral) follow the anterior surface of the sacrum to the lumbosacral level where they empty into the hypogastric veins, which in turn flow into the common iliacs at the sacroiliac joints. The common iliacs are short, continuing cephalad only to the level of the fifth lumbar body where they fuse to form the inferior vena cava to the right of the spine. Due to the low venous pressure, the numerous bypasses and multiple communicating channels, the blood flow may be in any direction depending upon pressure changes (Batson[1]).

3. Bucy, P. C. Blood vessel tumors of spinal canal. *Surg. Clin. North America*, 1932, *12*, 1323–1337.
4. Craig, W. M., and Shelden, C. H. Tumors of cervical portion of spinal cord. *Arch. Neurol. & Psychiat.*, 1940, *44*, 1–16.
5. Gray, Henry. Anatomy of the Human Body. Twentieth edition. Lea & Febiger, Philadelphia, pp. 667–673.
6. Rasmussen, T. B., Kernohan, J. W., and Adson, A. W. Pathologic classification, with surgical consideration, of intraspinal tumors. *Ann. Surg.*, 1940, *111*, 513–530.
7. Robins, S. A., and Shapira, A. A. Value of hysterosalpingography; study of 1,000 cases. *New England J. Med.*, 1931, *205*, 380–395.
8. Sobotta, Johannes. Atlas of Human Anatomy. Sixth edition. Vol. 1. G. E. Stechert & Co., New York, 1928.
9. Spurling, R. G. Practical Neurological Diagnosis. Second edition. Charles C Thomas, Springfield, Illinois, 1940.
10. Strain, W. H., Plati, J. T., and Warren, S. L. Iodinated organic compounds as contrast media for radiographic diagnosis. I. Iodinated aracyl esters. *J. Am. Chem. Soc.*, 1942, *64*, 1436–1440.
11. Strain, W. H., Plati, J. T., and Warren, S. L. Iodinated organic compounds as contrast media for radiographic diagnosis. II. Ethyl esters of iodinated straight and branched chain phenyl fatty acids. *J. Am. Chem. Soc.*, 1943, *65*, 1273.
12. Strain, W. H. Personal communication and unpublished material.
13. Tilney, F., and Riley, H. A. Form and Functions of the Central Nervous System. Second edition. Paul B. Hoeber, Inc., New York, 1923.
14. Weitzner, G. Entrance of iodized oil into venous circulatory system during uterography. *J. Am. M. Ass.*, 1935, *104*, 545–546.
15. White, H. L., and Rolf, Doris. Rapid micro method for determining diodrast and inorganic iodide iodine in blood and urine. *Proc. Soc. Exper. Biol. & Med.*, 1940, *43*, 11–14.

OSTEOGENIC SARCOMA AND CHONDROSARCOMA

WITH SPECIAL REFERENCE TO THE ROENTGEN DIAGNOSIS

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THE problem of the correct diagnosis of tumors of bone is a very difficult and important one which often faces the clinician, roentgenologist and pathologist. When confronted by an advanced and so-called "typical" bone tumor the diagnosis is, in many instances, made with facility, but in the early cases with minimal changes, it is a great deal more difficult. It is these early cases in which we are primarily interested, since the earlier a correct diagnosis is made the earlier treatment can be instituted. Earlier recognition of cancer in general is regarded as a primary source of hope for future lowering of mortality rates from cancer, although with regard to bone tumors in particular, some investigators[7,15] have presented evidence suggesting the advisability of delaying surgical treatment. Nevertheless the outlook for patients with malignant tumors of the skeletal system is so serious that all concerned would like to be able to give the patient and his family an idea as to the prognosis as soon as possible.

Codman has stated that any hospital which is doing its best for cases of bone tumor will arrive promptly at the correct diagnosis in the majority of cases of osteogenic sarcoma independently in each department concerned, and that if either the clinician, roentgenologist or pathologist has any doubt then probably all should and do have doubt.[4]

In making the diagnosis, details of the history including rapidity of growth, pain, duration of symptoms, trauma, pathological fracture, and previous treatment must be taken into full consideration, and full use must be made of the roentgen examination, in which the roentgenograms should be of the highest technical perfection possible, multiple views including oblique views, soft and bony tissue exposures and stereoscopic exposures.[1,8] Finally a pathologic examination of the tissue must be made, either by biopsy or by removal of the entire lesion. Of these methods of diagnosis, the first two can be carried out without causing the patient any additional pain, discomfort or complications.[1] The last is more serious, and Meyerding and Valls[17] feel that a microscopic examination of the tumor tissue by biopsy should be made before any amputation is done. Several of our patients, especially Case 24, in which amputation was performed for an inflammatory lesion, give emphasis to this statement.

This paper is principally concerned with the accuracy of and difficulties met in diagnosis of these lesions by roentgenographic examination. When confronted with a lesion of bone there are three questions which must be answered by the roentgenologist. These are: "Is this a tumor or some other condition?" "If a tumor, is it benign or malignant?" and "If a malignant tumor, is it primary or secondary?" Many conditions, notably infectious lesions of bone, may be confused with bone tumors, and while the history, clinical picture and laboratory studies will help in many instances, biopsy is often necessary. The roentgenologic appearance will often answer the second question, and a thorough search of the entire skeletal system and of other parts of the body for multiple metastases or possible primary lesions may give the answer to the third question.[8,21]

One factor which tends to increase the roentgenologist's difficulties is the multiplicity of classifications of tumors of bone which have been used. While the Registry of Bone Sarcoma of the American College

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of Surgeons has presented a classification and done much to clarify the situation by collecting a large group of cases,[4] many other classifications or modifications of the Registry classification have been advanced.[8,14,16] In 1939[5] the original[4] Registry classification was revised, one of the principal changes being the recognition of the chondrosarcomas as a distinct group as advocated by Phemister;[19] other classifications, notably that of Geschickter and Copeland,[8] have also recognized the necessity of separating the chondrosarcomas from the general group of osteogenic tumors. As pathologists change their opinions as to what constitutes any one group it is well for roentgenologists to review their roentgenograms of this group in an effort to correlate what they see with the new pathological diagnosis. In this paper we have followed the classification of the Registry (although only one of our cases has been registered with that group).

This paper is an attempt to evaluate the difficulties and pitfalls in the roentgen diagnosis of primary malignant bone tumors, and to correlate the pathologic picture with the roentgen picture. Some authorities believe that the diagnosis of sarcoma of bone can be made on the basis of the roentgenogram alone,[10,15] but others disagree.[8,18] It was in an effort to determine our experience in the matter that the following study was undertaken. The clinical histories, roentgenograms and pathologic sections of all cases of primary malignant tumors of bone which had been seen in this hospital since January 1, 1931, were restudied and many of the tumors were reclassified. Those classified as osteogenic sarcoma and chondrosarcoma, together with several cases which might be confused with these conditions, are included in this series. Only those cases in which the available clinical data or pathologic material were inadequate for classification were excluded. The roentgenograms on these cases were restudied in an effort to form some conclusions as to the characteristics of these lesions, and the original roentgenologic diagnosis was checked

Table I

Case No.	*Original Roentgenologic Diagnosis*	*Final Pathologic Diagnosis*
1	Uncertain, possible malignant bone tumor, possible osteogenic or chondrosarcoma	Osteogenic sarcoma
2	Osteogenic sarcoma	Osteogenic sarcoma
3	Malignant osteogenic sarcoma	Osteogenic sarcoma
4	Either osteogenic sarcoma or Ewing's tumor	Osteogenic sarcoma
5	Probably a growth	Osteogenic sarcoma
6	Atrophic changes and possible hypertrophic changes; appears to be a result of infection	Osteogenic sarcoma
7	Not recorded	Osteogenic sarcoma
8	Sclerosing osteogenic sarcoma	Chondrosarcoma
9	Giant cell tumor	Chondrosarcoma
10	Possibly a malignant enchondroma	Chondrosarcoma
11	Not recorded	Chondrosarcoma
12	First examination: nothing abnormal; second examination: uncertain, possibly a metastatic or primary tumor	Chondrosarcoma
13	Probable osteoma of the scapula	Chondrosarcoma
14	Possible luetic lesion; enchondroma cannot be excluded	Chondrosarcoma
15	Request further examination	Chondrosarcoma
16	Suggestive of osteo-enchondroma or osteogenic sarcoma	Chondrosarcoma
17	Not recorded	Chondrosarcoma
18	Metastatic malignancy	Chondrosarcoma
19	Probably chondroma	Osteogenic sarcoma
20	Osteogenic sarcoma	Chondrosarcoma?
21	Malignant tumor—periosteal fibrosarcoma	Osteogenic sarcoma

Fig. 1. Case 1. Osteogenic sarcoma. The roentgenogram shows a primarily osteoblastic growth involving the lower end of the femur giving a "cottony" appearance of the bone.

with the final pathologic diagnosis in an effort to determine the accuracy of our original impression. The original diagnoses are included in Table I.*

OSTEOGENIC SARCOMA

There are 7 cases of osteogenic sarcoma in this series. Abstracts of their histories follow:

Case I. H. K., white male, aged eighteen, was admitted June 7, 1938, complaining of a painful left knee for five months with slight swelling in that region. On June [illegible], a left mid-thigh amputation was done, but by December, 193[illegible], lung metastases were demonstrable. The course was continuously retrogressive and the patient died early in 1940. A postmortem examination showed large bony lung metastases and metastases to the lymph nodes in the pelvis.

The roentgenographic examination of the femur shows marked sclerosis of the medullary cavity with destruction in some areas of the cortex, giving the bone a mottled cottony appearance. There was some periosteal proliferation, but no periosteal lipping or radiating spicules of bone (Fig. 1).

Pathologically this was considered to be a sclerosing osteogenic sarcoma. Direct transformation of the proliferating connective tissue of the tumor into neoplastic bone was especially conspicuous in the pulmonary metastases.

Case 2. C. E., white male, aged twenty-one, was first seen on June 25, 19[illegible], complaining of pain, swelling and stiffness of the right knee for six months. He was given preoperative roentgen therapy, a total dose of [illegible] being delivered to three fields over the tumor during the ensuing three months [illegible]

Fig. 2. Case 2. [illegible]

* [illegible]

constant potential, 15 ma., 0.5 mm. Cu and 2 mm. Al, 50 cm. skin target distance). On September 18, 1934, the leg was amputated, but by January, 1935, lung metastases were demonstrable and he died in May, 1935.

The roentgenographic examination before irradiation showed an area of destruction and sclerosis involving the lower end of the right femur with a fairly large soft tissue tumor containing some calcification. There was periosteal reaction and new bone formation extending into the overlying soft tissues creating a "sun-ray" appearance on the posterior surface of the bone (Fig. 2).

On pathologic examination this tumor showed cellular areas of predominantly osteolytic growth, but areas of sclerosis were also present.

Case 3. W. J., male, Negro, aged sixteen, was admitted on July 8, 1942, complaining of a sore left leg for six weeks. There was marked swelling of the upper part of the leg just below the knee and extending downward for about 6 inches. On July 23, 1942, a left lower thigh amputation was done. Lung metastases were demonstrable in March, 1943, and the patient died in November, 1943.

The roentgenographic examination showed evidence of bone destruction involving the shaft of the left tibia just below the epiphyseal line, with bony spicules radiating into the soft tissues. Roentgenographically, the process was largely a destructive one (Fig. 3), whereas the microscopic appearance was for the most part that of a sclerosing osteogenic sarcoma. Considerable cartilage was present in the tumor.

Case 4. J. W. H., white male, aged sixteen, was admitted on November 23, 1936, with pain and swelling in the right knee since the previous September. There was an osseous tumor about 8 by 5 cm. on the mesial aspect of the right knee. The same day a mid-thigh amputation was done. The boy developed metastatic lesions in the lungs within a year, and it was reported to us from another hospital that there was a similar lesion in the other knee. He died on June 27, 1938.

The roentgen examination showed an area of bone destruction involving the lower end of the right femur, and a large soft tissue tumor which contained some streaks of calcification. There were periosteal elevation and lipping, but no perpendicular striations. The process was almost entirely osteolytic (Fig. 4*A*).

Fig. 3. Case 3. Osteogenic sarcoma. This case demonstrates the typical radiating spicules and "sun-ray" appearance of osteogenic sarcoma. There is no marked sclerosis at this time.

The tumor was composed of large polyhedral cells with little intercellular substance, but including a small amount of osteoid tissue. Evidences of old and fresh hemorrhage were conspicuous, and there were many blood-filled spaces lined with tumor cells. We have classified it as an osteolytic osteogenic sarcoma (Fig. 4*B*).

Case 5. M. M. L., female, white, aged forty-six, was admitted on November 19, 1934, with a steadily growing mass on the anterior aspect of the right shoulder in the region of the coracoid process. A biopsy was taken, and on January 27, 1935, a radical excision of the tumor and parts of the scapula and clavicle was performed, but local recurrence and lung metastases developed and she died early in 1936.

The roentgen examination showed an osteoblastic process in the region of the coracoid process of the right scapula which had extended into and destroyed the cortex.

Pathologic examination showed a characteristic osteogenic sarcoma, predominantly of the sclerosing type.

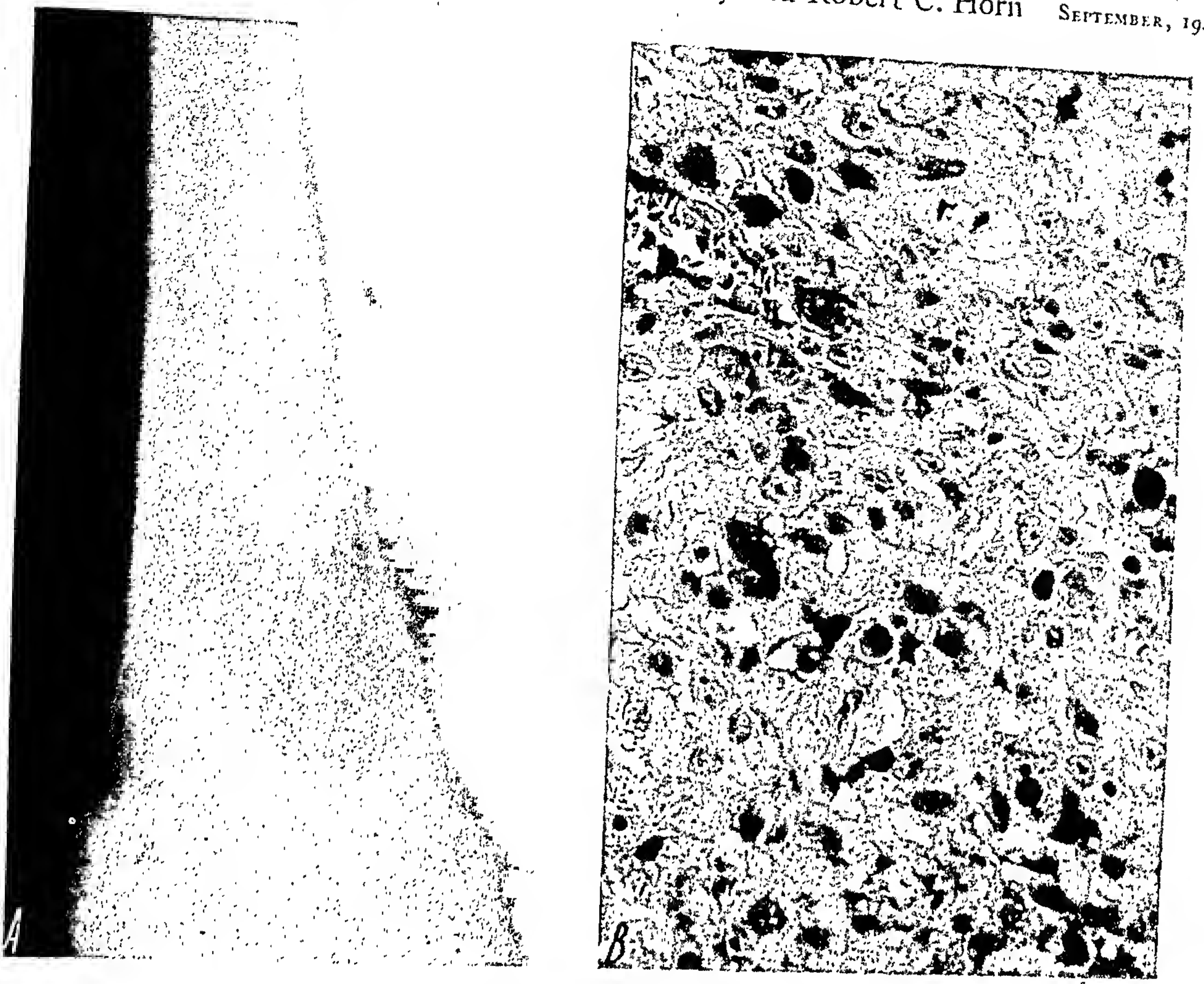

FIG. 4. Case 4. Osteogenic sarcoma. *A*, this case demonstrates an almost completely osteolytic lesion with a large soft tissue tumor without calcification. There is some periosteal reaction. *B*, photomicrograph of the same osteolytic osteogenic sarcoma (×620).

CASE 6. W. H., white male, aged eighteen, was admitted on September 7, 1934, complaining of stiffness, pain and swelling in the left knee for one month. The patient was given irradiation with a total dose of 2,000 r in air (165 kv. constant potential, 15 ma., 0.5 mm. Cu and 2 mm. Al, 50 cm. skin target distance, 15 by 15 cm. field) during the next month and a half. On October 29 a mid-thigh amputation was carried out but there were lung metastases within two months and the patient died in February, 1935.

The roentgenographic examination of the upper leg showed some periosteal reaction and lipping of the tibia with dislocation of the head of the fibula. The destruction of the lateral half of the head of the tibia became more marked, and all of the changes progressed very rapidly in spite of roentgen therapy.

Because of the extensive necrosis, presumably due to irradiation, the pathologic material is poor. The anaplastic character of the remaining viable cells leaves little doubt as to the histologic diagnosis of malignancy, but more exact pathologic classification is difficult. We have classified it with the osteolytic osteogenic sarcomas.

CASE 7. S. R., white male, aged thirteen, was admitted on August 15, 1932, with a history of pain and swelling of the left lower leg following a blow three weeks before. On August 17 a biopsy of the lesion was done and on August 26 an amputation at the lower thigh level was performed. By January, 1933, lung metastases were present and the patient died one year later.

The roentgenograms in this case have been destroyed.

Pathologic examination of the tissue showed an osteolytic tumor with small amounts of osteoid tissue and cartilage.

CHONDROSARCOMA

Since 1931 we have had 11 cases in which a diagnosis of chondrosarcoma was estab

lished. Brief abstracts of the histories on these patients follow:

Case 8. A. P., white female, aged fifteen, was admitted on October 15, 1935, complaining of a painful lump on the right thigh for four months. The day after admission a hip joint disarticulation was done. The patient was living and well on February 1, 1944 ($8\frac{1}{4}$ years after disarticulation).

The roentgenologic examination showed a diffuse process involving the lower half of the right femur characterized by destruction of the medullary portion of the bone with some evidence of periosteal proliferation. There were striking perpendicular striations with flattened tops, as seen in several other cases in this group (Fig. 5*A*).

The tumor was composed of lobules of fairly mature cartilage separated by very cellular tissue having the appearance of embryonal cartilage. There were areas of calcification (Fig. 5*B*).

Case 9. M. P. H., female, white, aged twenty two, was first seen on January 22, 1935, complaining of pain in the upper part of the left tibia. Following roentgenographic examination she was given roentgen therapy to the knee, but there was little improvement. In June, 1937, the tumor was curetted. Less than a year later, a large local recurrence developed, and on April 18, 1938, a mid-thigh amputation was done. The patient was well on April 4, 1944 (6 years after amputation).

Roentgenologically, the original examination showed an area of bone destruction involving the inner half of the head of the tibia, but the cortex was intact (Fig. 6*A*). After prolonged irradiation the lesion developed small scattered calcified densities. The cortex was never broken. The diagnosis of giant cell tumor was made from the roentgenograms (Fig. 6*B*).

The pathologic examination showed a heavily calcified chondrosarcoma. Occasional bone trabeculae were formed in the cartilaginous matrix of the tumor. This sarcoma is considered

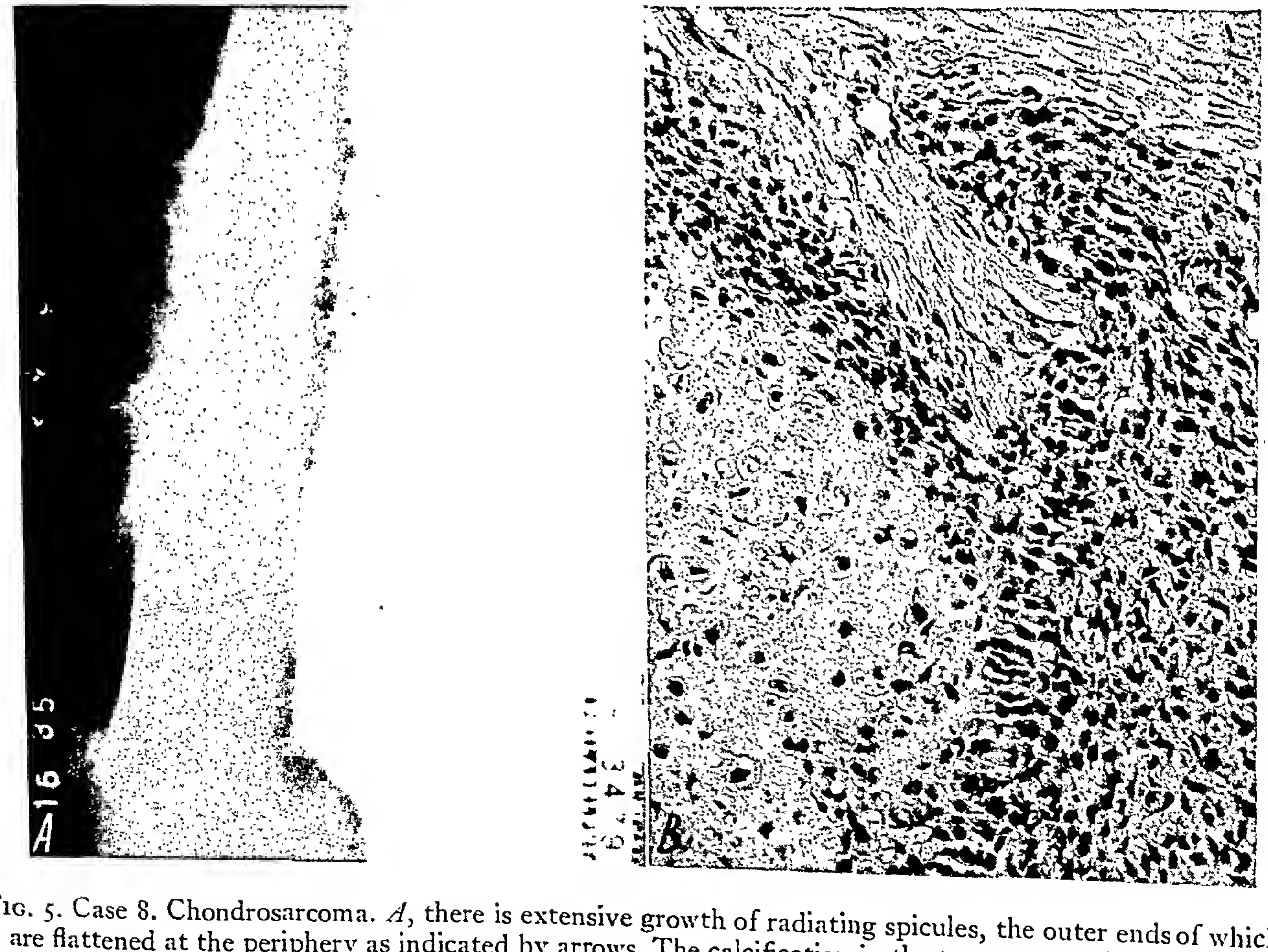

Fig. 5. Case 8. Chondrosarcoma. *A*, there is extensive growth of radiating spicules, the outer ends of which are flattened at the periphery as indicated by arrows. The calcification in the tumor occurs in large flecks. *B*, photomicrograph showing a lobule of well differentiated cartilage with embryonic cartilaginous tissue, containing many spindle and stellate cells about the periphery (×300).

FIG. 6. Case 9. Chondrosarcoma. *A*, a roentgenogram made when the patient was first seen showing a large destructive lesion which has not broken through the cortex. *B*, two and a half years later this lesion contains many flecks of calcium, at arrows. This tumor still leaves the bony cortex intact. *C*, photomicrograph of secondary chondrosarcoma of tibia (×300).

to represent malignant change in a chondroma which was benign at the first examination (Fig. 6*C*).

FIG. 7. Case 10. Chondrosarcoma. The roentgenogram shows a large tumor leaving no trace of the cortex and containing flecks of calcium.

CASE 10. G. H., white male, aged fifty-six, was admitted on March 30, 1943, with a lump on his right side in the mid-axillary line which had rapidly increased in size in the previous year. A resection of the tumor was done the next day and the patient was clinically well on April 4, 1944 (1 year after operation).

The roentgen examination showed a tumor the size of an orange arising from the seventh rib in the mid-axillary line which had expanded the cortex leaving no trace of the original cortical line. Small spotty deposits of calcium could be seen (Fig. 7).

Examination of the specimen showed the remnants of the cancellous portion of the rib in the center of the tumor. Sections showed a highly cellular tumor with a matrix of myxomatous tissue and embryonal cartilage. A good deal of bone was present but it appeared to be entirely reactive. The history suggests that this may have been secondary to a chondroma, but we have no roentgen or pathologic evidence of this.

CASE 11. F. H., white female, aged forty, was admitted to the hospital on March 12, 1944, with a history that one year previously a tumor of the rib had been noted in a routine roentgen examination of the chest. It gave no symptoms until about a month before admission when there was pain on deep inspiration. A segment of the rib 4 cm. long was resected the next day. The patient is entirely well at this time.

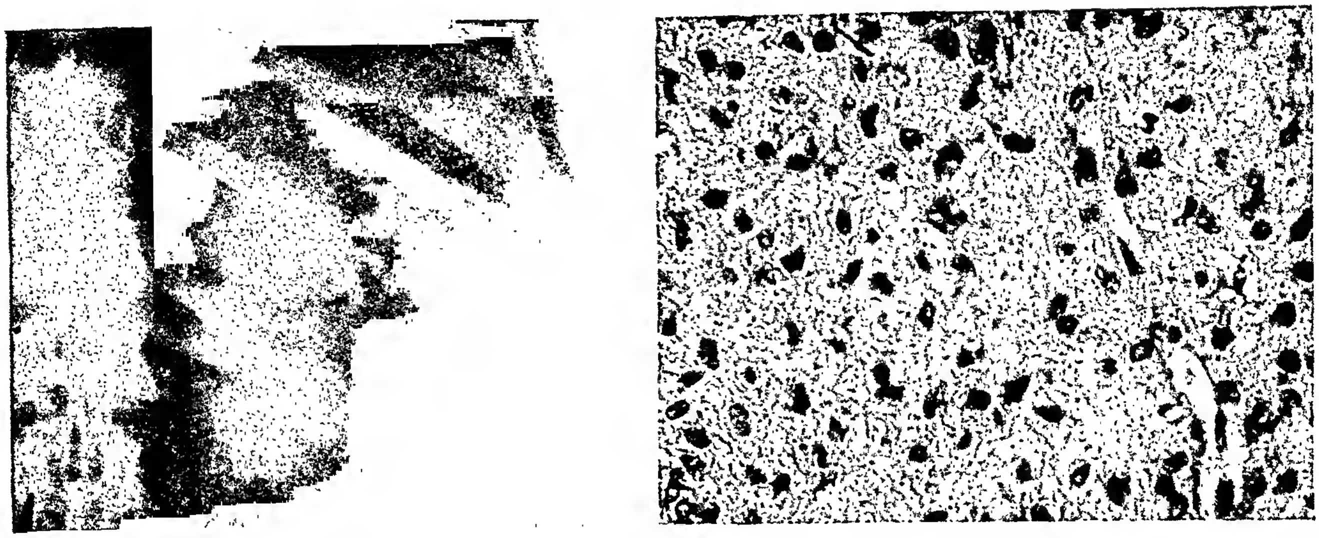

Fig. 8. Case 11. Chondrosarcoma. *A*, this lesion expands the cortex of the rib but does not break through. It contains no calcification in the center. *B*, photomicrograph shows the immature character of the cartilage, its marked cellularity and the plump appearance of the cells (×620).

The roentgen examination showed a central tumor in the eleventh rib. The cortex was slightly expanded but still intact. There were several small osteochondromas demonstrable in this patient (Fig. 8*A*).

The tumor was small and well circumscribed, being still enclosed within a shell of cortical bone. The diagnosis of malignancy was based on the histopathologic findings of marked cellularity, the general plump appearance of the nuclei, occasional binucleated cells, and mitotic figures. The matrix was almost wholly myxomatous. We have considered this histopathologic picture as indicative of early malignant change in a chondroma (Fig. 8*B*).

Case 12. J. M., male, white, aged thirty-six, was first seen by us on October 31, 1942, complaining of pain in the upper left femur for two months. On December 11, he was re-examined after the surgeon had made a clinical diagnosis of tumor because of the patient's severe symptoms. Disarticulation at the hip joint was advised but refused by the patient. He was given

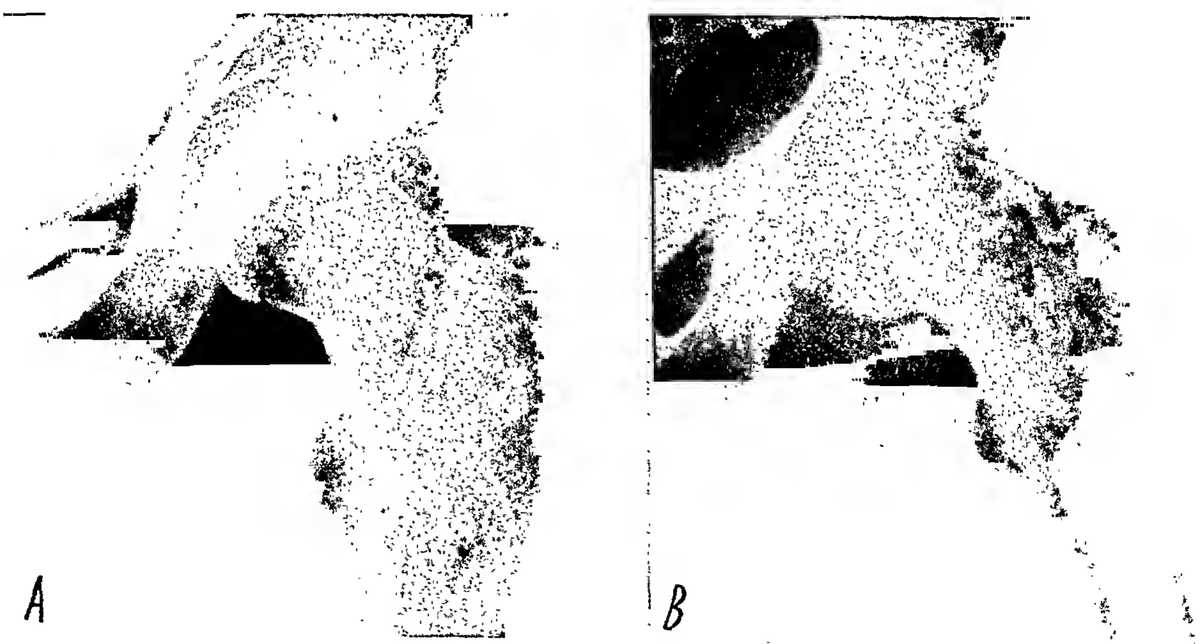

Fig. 9. Case 12. Chondrosarcoma. *A*, roentgenogram made October 30, 1942, shows no evidence of a tumor. The tumor was first seen in a roentgen examination made December 11, 1942. *B*, roentgenogram made June 6, 1943, shows a large soft tissue tumor with destruction of the trochanters and flecks of calcification scattered throughout the soft tissue mass.

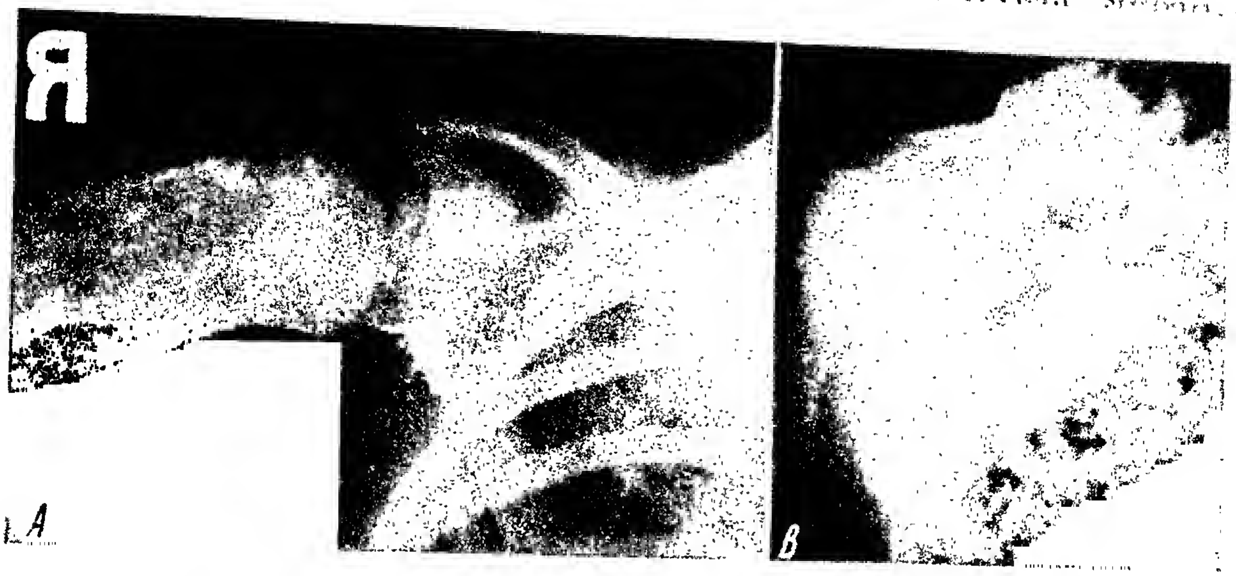

Fig. 10. Case 13. Chondrosarcoma. *A*, roentgenogram made of the shoulder in 1922 showing osteochondromas of the scapula and humerus. *B*, in 1934 the tumor of the scapula had undergone malignant change and was a huge tumor with large flecks of calcification scattered throughout. The tops of some of these were flattened, as in Figure 5.

extensive roentgen treatment and Coley's toxins, both before and after biopsy, but the course was steadily retrogressive and he died at home on October 22, 1943, after the tumor spread to the ilium and metastasized to the lungs.

Roentgen examination made in October showed very slight rarefaction of the greater trochanter of the femur, but these slight changes were overlooked at that time (Fig. 9*A*). In December there was a definite destructive lesion of the greater trochanter and the neck of the femur, which as time went on showed flecks of calcification in a large soft tissue tumor (Fig. 9*B*).

Biopsy of the tumor showed fairly well differentiated but unusually cellular cartilage and small foci of myxomatous tissue containing bizarre cells.

Case 13. H. C., white male, aged thirty, was admitted on November 6, 1936, complaining of a rapidly growing lump on the right shoulder. Since the age of three or four many small lumps had been noted on his arms and legs and on other bones, and examination at the time of admission showed many exostoses. Three days later the greater part of the scapula was excised, but local recurrences were noted in January, 1937, and the patient died of multiple metastases on March 11, 1937.

The roentgen examination of this patient was of particular interest because in our file was a roentgenogram of the scapula which had been made twelve years previously and which showed an osteochondroma (Fig. 10*A*). At the time of admission the scapula was almost entirely replaced by bony tumor which showed an irregular pattern of calcification, the calcification occurring in large irregular flecks. These were flattened along the periphery as was seen in Case 8 (Fig. 10*B*).

Histopathologically this was an anaplastic spindle cell tumor with occasional areas of myxomatous tissue or of embryonal or calcified cartilage.

Case 14. M. R., white female, aged sixteen, was admitted on November 4, 1933, with a lump on the anterior surface of the right shin of ten months' duration. A therapeutic test with bismuth was carried out (in spite of a negative blood Wassermann) because the possibility that the lesion was luetic was suggested. A trial of irradiation did not produce any beneficial change. In June, 1934, the tumor was excised but the specimen was lost and pathologic examination was not made. There was a recurrence in January, 1935, and at that time the tumor was excised. Several days later it was excised again, also without pathologic examination. Extensive recurrence took place, and on April 12, 1935, a mid thigh amputation was done. The patient was given [illegible] to the lungs and to the stump, but [illegible] recurred in the stump in September, 1936, and the patient died on March [illegible], 1937, with [illegible] metastases.

The roentgen examination showed a lesion of the anterior surface of the tibia characterized by thickening of the cortical bone, surmounted by a soft tissue area containing small discrete flecks of calcification (Fig. 11*A*). This gradually grew larger, but after the second removal the recurrence showed definite periosteal proliferation and coarse perpendicular striations with a large soft tissue tumor, much like the original appearance in Case 8.

The tumor was predominantly myxomatous. The history suggests the possibility that the sarcoma developed at the site of a pre-existing benign lesion, and an osteochondroma was present at the upper end of the tibia. However, there are no roentgenographic or histopathologic findings which give support to this possibility (Fig. 11*B*).

Case 15. J. D., white female, aged fifty-two, was first seen in August, 1931, complaining of swelling and stiffness of the right knee for several months. Following examination here she went to the Johns Hopkins Hospital where an amputation just above the mid-thigh level was done. She developed a local recurrence in the stump which extended into the pelvis, and pulmonary metastases, and she died on June 8, 1933.

The roentgen examination showed an increase in the width of the right femur with marked subperiosteal reaction. The distinctness of the trabeculae was lost. The patient did not return for further examination as we requested (Fig. 12).

The diagnosis of chondrosarcoma arising in Paget's disease was made by Drs. J. C. Bloodgood and Charles F. Geschickter. We have been permitted to study the sections which show a highly cellular tumor including myxomatous areas and abundant neoplastic cartilage. Nothing was seen in the sections which we studied to substantiate the diagnosis of Paget's disease, but the roentgen examination is suggestive of this condition. We have classified this lesion, therefore, as a secondary chondrosarcoma.

Case 16. W. K., male, white, aged sixty-five, admitted April 17, 1937, complaining of a continuously growing lump on the left shoulder

Fig. 11. Case 14. Chondrosarcoma. *A*, when the patient was first seen, the roentgenogram showed a small soft tissue mass containing irregular calcific deposits, in addition to the bone involvement. After the second recurrence this resembled Figure 5. *B*, photomicrograph of the tumor of which the roentgen appearance is shown in Figure 11*A*. Histopathologically this tumor is similar to Case 8, Figure 5*B* (×300).

FIG. 12. Case 15. Chondrosarcoma. The involved knee shows a widened bone with widened trabeculae and a generalized smudgy appearance of the bone. This was thought to be localized Paget's disease with sarcomatous change.

for two years. One year before this lump was first noticed he had fallen on that shoulder, but there were no known bad effects from the fall for one year. Two days after admission the tumor and greater part of the scapula were removed, but there was a local recurrence in November, 1937, and the patient died in August, 1938, with lung metastases.

Roentgenographic examination showed a large tumor arising from the left scapula which contained mottled calcification similar to although not as extensive as that seen in Case 13.

Much of the tumor was myxomatous or composed of closely packed, large spindle cells. On the basis of the clinical history it was classified as probably having arisen secondarily in a preexisting osteochondroma.

CASE 17. E. C., female, white, aged twenty-two, was admitted on October 24, 1931, complaining of pain in the lower back and left leg. A large mass had been previously noted and diagnosed as sarcoma in another hospital. Chordotomy was done for the relief of pain, but no specific treatment was carried out for the tumor. The patient died six months postoperatively. The tumor proved to be a chondrosarcoma, but we are unable to evaluate the roentgenologic features, as these roentgenograms have been destroyed.

CASE 18. J. K., male, white, aged fifty-one, was admitted on April 27, 1942, for inguinal herniorraphy. When he complained of pain in his left thigh radiating down his leg postoperatively, a roentgen examination was done and the diagnosis of metastatic carcinoma was made. However, on August 11, 1942, the lesion was biopsied and diagnosed as a chondrosarcoma. The sections showed calcified cartilage and myxomatous tissue. No specific treatment was carried out and the patient became progressively cachectic and died on September 20, 1942, although no metastatic lesions were demonstrated clinically or roentgenologically. Autopsy was not performed.

FIG. 13. Case 18. Chondrosarcoma. The involved ilium shows generalized sclerosis with no destruction and no soft tissue tumor demonstrable in this view. Later a soft tissue tumor developed on the lateral side which contained flecks of calcium similar to those in the other chondrosarcomas.

The roentgenographic examination of this patient showed a dense sclerosis of the left ilium with loss of bony trabeculation. This was thought to be metastatic carcinoma of an osteoblastic type. As time went on, this spread and involved the head of the left femur (Fig. 13). The other bones were normal.

ROENTGENOGRAPHIC FEATURES

Comparison of the roentgenograms of this series of patients with the classical descriptions of these tumors of bone brings out several interesting points. Sclerosing osteogenic sarcoma is described as occurring characteristically on the shaft side of the epiphyseal zone and showing mottling due to destruction and sclerosis within the bone. In some instances the growth extends beyond the epiphyseal zone as observed in Cases 1 and 2. The cortex is incompletely preserved although in spots it is obscured by calcification extending into the periosteal and medullary zones. The periosteum is raised above or below the tumor giving periosteal lipping or the so-called "Codman triangle"[12] and spicules of new bone are laid down perpendicular to the cortical surface producing the shaggy "sun-ray" appearance. There may be extension into the soft tissues.[8,10,12,13,21]

Osteolytic osteogenic sarcoma manifests itself by a central area of irregular destruction which eventually extends through the cortex. It is asymmetrically located and there is periosteal reaction. The soft tissues are often involved.[8,10,12,13,21]

In many cases the two types are coexistent, and these cases exhibit more definitely the findings which have been described by Codman as occurring in every osteogenic sarcoma. According to him, these are tumors of invasive character with combined central and subperiosteal involvement in which fragments of the shaft remain. They may be either osteolytic, osteoblastic or both, and there is involvement of the soft tissues. He feels that if these characteristics are not fulfilled one must suspect that the condition is not osteogenic sarcoma.[4]

Roentgenologically, Case 1 in our series is as nearly pure sclerosing osteogenic sarcoma as any we have observed, but even in this there is destruction of areas of the cortex which can be seen in the more highly penetrated roentgenograms. In those made for soft tissue detail it can be seen that this tumor has invaded the soft tissues of the leg. The sclerosis gives a cottony appearance to the lower end of the femur. It is important to note that in this patient there were none of the radiating spicules which have been called typical of osteogenic sarcoma.

Case 4 in this series is as purely osteolytic osteogenic sarcoma as we have seen. The cortex on the mesial side of the bone was destroyed and there was a large soft tissue tumor. This was a far advanced lesion when it was first seen. There was "classical" periosteal lipping. Cases 2 and 3 would come under the heading of tumors of a mixed type, roentgenographically, as would the other cases in which we have had roentgenograms to study.

Case 6 is worthy of note in that it was probably the earliest case included in this series. At the time of the first examination there was only a small amount of periosteal elevation and lipping to indicate the presence of any pathologic lesion. This is one of the earliest signs of osteogenic sarcoma and should be carefully watched for in all patients complaining of persistent pain in a bone or joint.

Lichtenstein and Jaffe[11] have divided the chondrosarcomas into two groups, the central and peripheral. The roentgenographic findings in tumors of the central group can be divided into two subgroups, those which begin in the medulla, and others beginning in the cortex or just under the periosteum. The first group shows large thick-walled cavities tending to destroy the cortex. The areas of decreased density may show trabeculation, with central areas of multilocular destruction or foci of calcification scattered irregularly throughout the lesion. They occur in the ends of long bones and the cortex is perforated late. In our series

Cases 9, 10, and 11 fall in this group. The second subgroup shows a faintly visible shadow in the soft tissue next to the bone, raising the adjacent periosteum, frequently with no medullary and very little if any cortical involvement. The shadow is very faint and when calcification is present it is sparse and takes the form of radiating spicules at right angles to the cortex or large flecks. The entire lesion may cast so faint a shadow that the diagnosis of tumor may be missed on a limited roentgen examination.[8,10,11,12] Cases 8 and 14 in our series definitely fall in this classification. It is important to note that the perpendicular spicules spoken of as occurring in this tumor may be distinguished from those of osteogenic sarcoma because the former grow to greater length (sometimes an inch or more) while those of osteogenic sarcoma usually do not reach a length of over $\frac{3}{4}$ inch. In addition the radiating spicules occurring in chondrosarcoma show a flattened outer surface as if the outermost ends of the spicules were molded by the overlying muscles.

Secondary or peripheral chondrosarcoma developing on the basis of benign osteochondroma in the cartilaginous cap usually retains some of the underlying features of the primary growth but the edge becomes ragged and a large soft tissue mass develops which contains scattered irregular foci of calcification.[8,11] Those developing on the basis of Paget's disease show some of the features of Paget's, with added destruction of bone and perhaps pathological fracture. In our series Cases 13, 15, 16, and possibly Case 14 represent lesions of this type. All of these were large masses which showed irregular calcification. Case 14 developed perpendicular spicules which closely resembled those seen in Case 8 only after two local excisions and one incision of the tumor.

All of the cases in our series had one finding in common—the spotty flecks of calcification that were seen in the tumor mass. In some this was very dense (Case 13), in others quite sparse (Case 10) but all exhibited this feature to some degree. We believe that this is a significant finding, roentgenologically, in the differential diagnosis of these lesions.

The earliest case in this series was that recorded as Case 13, in which the first roentgen examination was reported as negative and nothing could be seen until six weeks later when there was beginning destruction of the neck of the femur. On reviewing the roentgenograms now, the impression is gained that there is some slight destruction of the neck which is probably of significance. This re-emphasizes the fact that minimal changes must be carefully watched for and mentioned, and then followed closely in order to ascertain their significance.

ATYPICAL CASES

In our series of malignant bone tumors there are 3 cases in which we are unable to correlate the roentgenologic and pathologic findings. Summaries of these cases follow.

Case 19. D. B., female, white, aged forty, was admitted on March 24, 1931, with a chief complaint of tenderness over the left knee for three months, and swelling for one month. There was a history of previous fracture in that region with satisfactory union about ten years previously. On March 25, a mid-thigh amputation was done. However, on January 11, 1932, several recurrent nodules were excised from the scar, and on April 5, 1933, re-amputation of the left thigh was carried out in spite of pulmonary metastases at that time. Extensive irradiation was given to the stump and pelvis but the patient died on August 1, 1933.

The roentgenographic examination showed a tumor of the medullary region of the lower end of the diaphysis which had extended into the external condyle of the femur. There was slight destruction of the cortex with breaking through at one point. The tumor contained flecks of calcification and suggestions of trabeculae, and the roentgenographic appearance was similar to that seen in Case 9 (Fig. 14A).

The tumor was composed of large spindle cells with no evidence of formation of cartilage, osteoid tissue or bone. Intercellular fibrillar material was abundant only in the recurrences. We have classified this tumor with the [illegible]

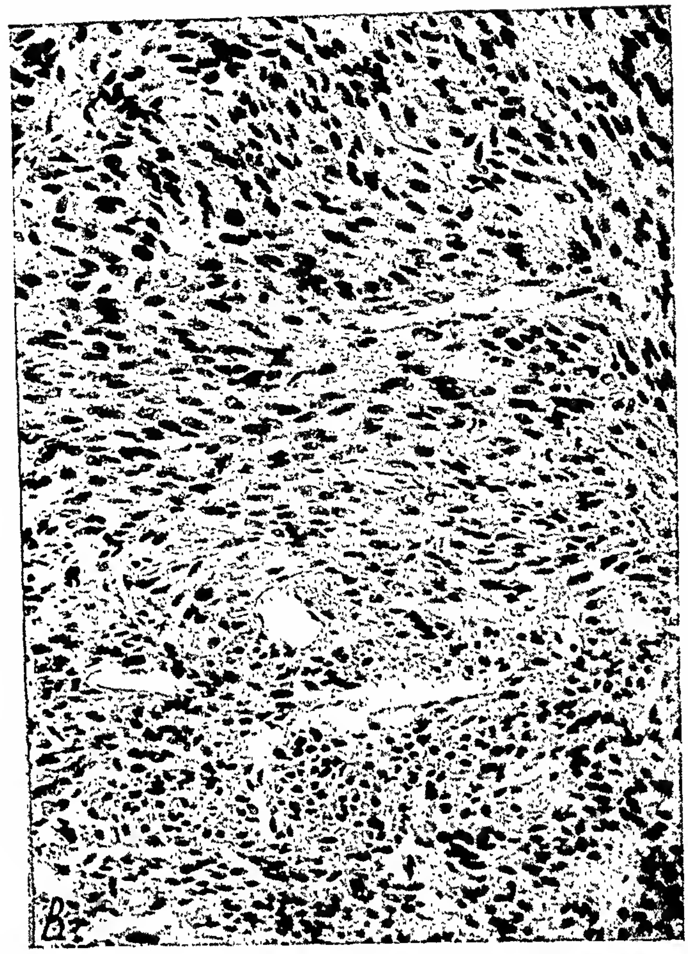

FIG. 14. Case 19. Osteogenic sarcoma. *A*, the tumor in the lower part of the femur shows a small area of destruction of the cortex at the upper part of the lesion, indicated by arrows. There are suggestions of trabeculae and deposits of calcium. *B*, photomicrograph shows a uniform picture of a spindle cell tumor without evidence of bone or cartilage formation. This appearance is typical of that of numerous sections of the original tumor and both recurrences (×300).

genic sarcomas pathologically, despite the failure to form tumor bone. It corresponds with the medullary fibrosarcomas which the Registry lists as a subdivision of the osteogenic sarcoma group[6] (Fig. 14*B*).

CASE 20. R. S., white male, aged twelve, was admitted on March 13, 1940, with a painful, stiff left knee of three weeks' duration. Five days later exploration was done, frozen sections were made and the leg was amputated above the mid-thigh level without removing the tourniquet. By November, 1940, there were recurrences in the stump, the inguinal lymph nodes were enlarged, presumably due to metastases, and lesions were demonstrated by roentgenologic examination in the lungs and opposite femur. The patient died on December 15, 1940.

The roentgen examination showed a fairly large soft tissue tumor involving the lower end of the right femur with periosteal elevation giving lipping and perpendicular spicules. There were many calcified areas in the soft tissue mass (Fig. 15, *A* and *B*). The roentgenograms of this tumor resemble those of Case 1, and would indicate that this tumor was an osteogenic sarcoma.

Sections of the tumor show cartilage which is highly cellular and extensively calcified, although some areas are myxomatous. This appearance, of course, points to the diagnosis of chondrosarcoma, but very little tissue is available for study and, in our opinion, the examination cannot be considered sufficiently complete to classify this tumor accurately as a chondrosarcoma, especially since the roentgen findings are so characteristic of osteogenic sarcoma (Fig. 15*C*).

CASE 21. J. L., male, Negro, aged seventeen, was admitted May 17, 1943, complaining of stiffness and swelling of the right knee for one month. After the roentgen interpretation, amputation was advised, but the patient's family

signed his release and took him to another hospital where the condition was diagnosed as osteomyelitis and the tumor incised. Uncontrollable hemorrhage followed and an emergency amputation was done on June 26, 1943. The patient died that night in shock. Permission for an autopsy was not obtained, but we secured the amputated leg for examination.

The roentgenographic examination showed a destructive lesion of the lower end of the femur with periosteal elevation above a large soft tissue mass. There were some flecks of calcification within the soft tissues, and destruction of the cortex of the bone was marked along the medial side (Fig. 16*A*).

Histopathologically, atypical and well differentiated cartilage formed a large part of this growth but it was considered more proper to classify it as an osteogenic sarcoma since in addition there was considerable formation of tumor bone or osteoid directly from the highly cellular matrix of the tumor (Fig. 16, *B* and *C*).

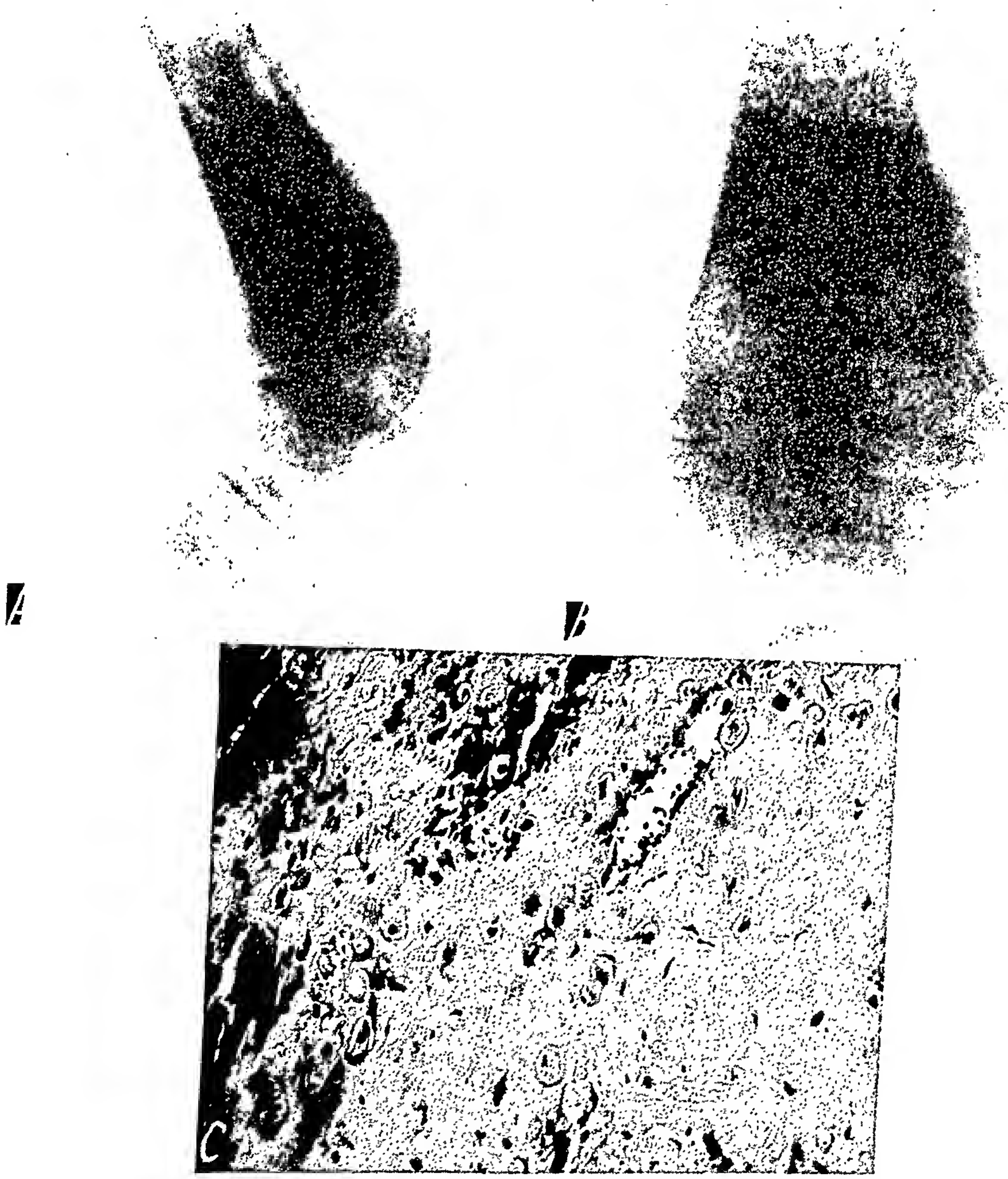

FIG. 15. Case 20. Questionable chondrosarcoma. *A*, lateral roentgenogram showing the combined sclerosis and destruction, with a large soft tissue tumor. *B*, anteroposterior view showing the radiating spicules. *C*, photomicrograph showing fairly well differentiated cartilage with extensive calcification (×300).

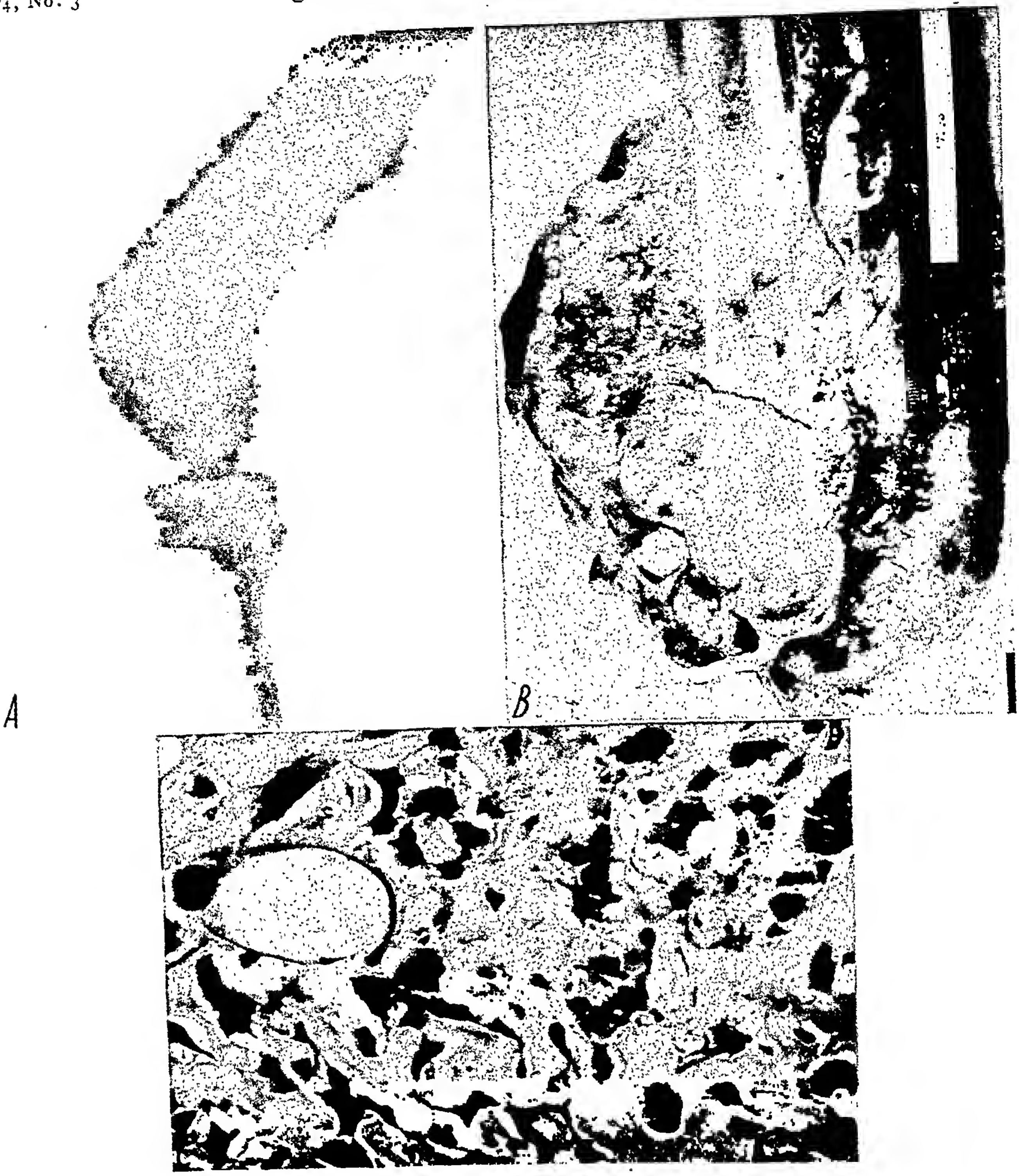

Fig. 16. Case 21. Osteogenic sarcoma. *A*, the roentgenogram shows a large soft tissue tumor lifting the periosteum and containing flecks of calcium as seen in chondrosarcoma. There is some destruction of the bone. *B*, the tumor contained abundant cartilage, which is evident in the peripheral portion of the lesion in the photograph (the fracture was produced in preparing the specimen). *C*, photomicrograph of the tumor illustrated in *B*, showing one of the areas where osteoid intercellular substance is being laid down (×620).

These 3 cases which have the roentgen characteristics of one lesion and the pathologic characteristics of another demonstrate that accurate diagnosis cannot always be made from the roentgen examination alone. Case 19, which could be classified as typical of the central chondrosarcomas from the roentgenologic appearance and closely resembling Case 9, showed the histopathologic pattern of medullary fibrosarcoma of bone. The clinical course of this patient differed from that of our other osteogenic sarcomas in that this woman had a recurrence in the scar, and in its unusual life

history of twenty-nine months. It resembles more closely the way in which our fatal cases of chondrosarcoma terminated. The osteogenic sarcoma cases, for the most part, developed lung metastases and died within a very short time. Ewing[6] describes a roentgenographic appearance similar to that of this case as characteristic of the medullary fibrosarcoma, and adds that such tumors usually run a slow course and are comparatively benign. Simmons[20] describes 2 cases of central osteogenic sarcomas of fibrous type which were diagnosed by the roentgen examination as giant cell tumor. They were treated by irradiation and died with lung metastases six and seven years respectively, after the beginning of treatment.

Both Cases 20 and 21 demonstrate the contention that the pathologic material from which the diagnosis is made must be adequate and representative of all parts of the tumor. While we feel that in Case 20 the roentgen appearance of the tumor was typical of the osteogenic sarcoma group, the two small sections of tissue still available to us for study do not confirm this, but would indicate that it is a chondrosarcoma. However, because of the roentgenographic appearance and the inadequacy of the pathologic material we feel justified in classifying this as a probable osteogenic sarcoma.

Case 21 is a tumor that roentgenographically was typical of the chondrosarcomas, in that there was a very large tumor with very little calcification scattered in large flecks as is often seen in that condition. However, after pathologic study it has been listed with the osteogenic sarcomas because of the finding of direct tumor osteoid formation. According to Lichtenstein and Jaffe[11] true tumor bone or osteoid tissue is never found in chondrosarcomas, and Geschickter and Copeland[8] describe true tumor bone as occurring in chondrosarcomas only next to the periosteum in the dense embryonal connective tissue strands dipping down from the margin of the tumor. This tumor might readily have been incorrectly classified as a chondrosarcoma if pathologic study had been limited to a biopsy or to a few small portions of the amputated specimen. In view of the abundance of cartilage in the tumor, such fragments might have been composed entirely of such tissue and the roentgenographic study would have lent support to the diagnosis of chondrosarcoma. We believe that it is the abundant cartilaginous tissue that accounts for the roentgenographic resemblance of this tumor to the other lesions in the chondrosarcoma group.

OTHER CASES CAUSING CONFUSION

Along with these tumors which fit into the series of osteogenic sarcoma and chondrosarcoma, we have observed five lesions of bone which have certain characteristics that might cause them to be confused with these two primary malignant tumors of bone. Abstracts of their histories follow.

Case 22. A. M., white male, aged twenty, was admitted November 18, 1931, complaining of pain in the left arm for seven months, with some loss of motion in that shoulder. After examination here, he was re-examined in another hospital and finally went to Memorial Hospital in New York where extensive roentgen therapy was given. He later returned here, and metastatic lesions were demonstrated in the lungs in October, 1932. He died in this hospital on April 6, 1933. Autopsy was not performed, but a specimen from the lesion of the shoulder was obtained for examination.

The only roentgenogram available at this time was made shortly before the death of this patient. It shows a destructive lesion of the upper end of the left humerus with a large soft tissue tumor containing many flecks and deposits of calcium. There is no evidence of sclerosis, but periosteal reaction can be seen below the tumor (Fig. 17). As this tumor had been followed from a very early stage, it was thought to be Ewing's sarcoma, but, on the basis of the first examination only, it could easily be confused with a chondrosarcoma, such as Case 12.

Sections of the tissue obtained postmortem for histopathologic examination showed a tumor of solid cords of moderately large cells with heavily stained nuclei and little cytoplasm.

There are few intercellular fibrils and no tumor bone or cartilage. Although this examination is fragmentary, because of this appearance and because of the initial response of the tumor to roentgen therapy, this is classified as a Ewing's tumor.

Case 23. J. K., male, white, aged sixty, was admitted on July 25, 1927, complaining of pain in his left knee of three months' duration. Various types of physiotherapy had been ineffectual elsewhere in relieving his pain. The diagnosis of osteogenic sarcoma was made by roentgenographic examination. He was given high voltage roentgen irradiation to the leg with immediate relief of pain, but was then transferred to the Philadelphia General Hospital. He died there on November 22, 1927. At postmortem examination a carcinoma of the prostate was found

Fig. 17. Case 22. Ewing's tumor in a late stage. This shows a large soft tissue tumor, considerable periosteal proliferation, destruction of the cortex and a pathological fracture. Note the similarity between this and Figure 9B.

Fig. 18. Case 23. Metastatic carcinoma from the prostate gland showing radiating spicules of bone.

on histopathologic examination, although it was not suspected from the gross appearance of the gland. This had given rise to multiple bony metastases, including those to the right femur.*

Roentgenologic examination showed involvement of the lower two-thirds of the femur with a diffuse periosteal osteoblastic process with coarse radiating spicules covering almost the entire length of bone. The shadow of the cortex was preserved in spite of moderate destruction which could be seen in the over-penetrated films. Later when roentgenograms were made of the lumbar spine and pelvis it was seen that there were diffuse osteoblastic metastases in those regions (Fig. 18).

Case 24. T. A., female, white, aged twenty-seven, was admitted on August 24, 1940, complaining of pain in her right thigh of six weeks' duration. There was some swelling in that region. Her blood count was normal. On August

* Dr. William Ehrich of the Department of Pathology, Philadelphia General Hospital, reviewed this material for us.

FIG. 19. Case 24. Osteomyelitis, showing bone destruction with some new bone formation. This shows no radiating spicules of bone, but the periosteal bone formation appears to come from the region immediately adjacent to the area of destruction.

26, 1940, an amputation was done above the mid-thigh level after a frozen section diagnosis of sarcoma was made. This woman is still living and well.

Roentgenologic examination showed an area of bone destruction in the middle of the shaft of the right femur with some new bone formation, but without striation. There was no periosteal lipping and none of the signs described as typical of osteogenic sarcoma was present. However, the original roentgen diagnosis was probable osteogenic sarcoma, and biopsy was suggested (Fig. 19).

Careful review of the histopathologic sections shows nothing that might be interpreted as evidence of malignancy. The findings are those of chronic suppurative osteomyelitis.

CASE 25. J. G., male, white, aged seventeen, was first seen by us on November 29, 1942, at which time he gave a history of pain in his left knee for a year, which was preceded by being kicked below the knee by a mule. Roentgenograms were made and the tibia was biopsied.

The roentgenographic examination showed periosteal proliferation with fine perpendicular striations around the upper outer surface of the tibia, but there was little or no evidence of destruction of the cortex. It was thought that this probably represented an early primary bone tumor. Subsequent examinations have shown that the lesion is disappearing (Fig. 20).

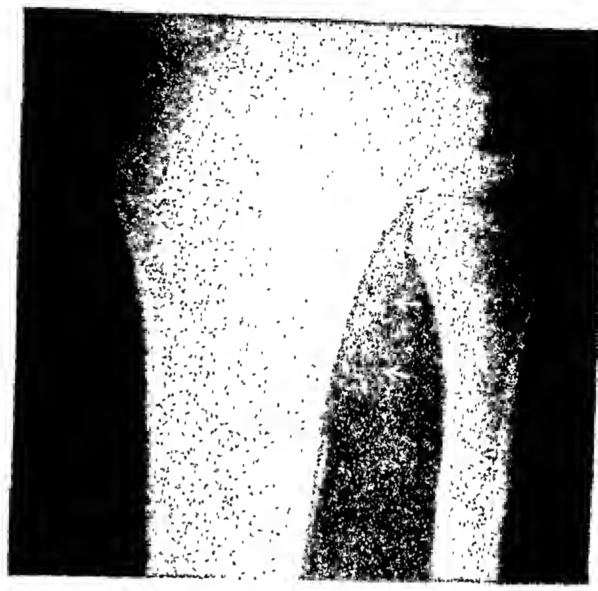

FIG. 20. Case 25. Periostitis, showing radiating spicules. (See footnote to Case 25.)

The pathologic examination of the tissue removed at biopsy showed a nonspecific periostitis with considerable fibrous tissue production but without any suggestion of tumor. This has been confirmed by the subsequent clinical course of the patient who is recovering without specific treatment of any kind.*

CASE 26. W. C., male, white, aged thirty-two, was admitted on April 22, 1930, with a history of pain in the right arm with enlargement for four months. Pathologic fracture had occurred in January, 1930. On April 23, a resection of the lesion was carried out and the gap was bridged by a bone graft from the fibula. A similar lesion of the right ulna was removed at

* Since this paper was submitted and twenty-five months after his first admission, this patient was readmitted with a large tumor involving the left inguinal lymph nodes. These nodes were excised and pathologic examination revealed a neoplasm very suggestive of "Ewing's tumor." In addition, information was obtained that before his first admission here the patient had received an unknown amount of irradiation over the tibial lesion at another hospital, after refusing biopsy. We have therefore reclassified this case as Ewing's tumor of the tibia with metastases to the inguinal lymph nodes, presuming that the irradiation previously given had eradicated pathologic evidence of the tibial neoplasm.

the same time. He was last seen in May, 1943, at which time he was living and well.

The roentgen examination showed an expanding, destructive, fusiform lesion of the middle of the humerus with a pathologic fracture. There was no sclerosis or periosteal proliferation. There was a cup-shaped lesion on one side of the ulna (Fig. 21).

The histopathologic examination after removal showed large areas of partially organizing hemorrhage and many blood-filled vascular channels, usually of capillary size but occasionally having smooth muscle in their walls. The tumor was diagnosed as a hemangioma.

COMMENTS ON DIAGNOSIS

From this entire series of cases several important points in the diagnosis of lesions of bone can be made. First, we believe that it is worth while to restate the fact that perpendicular striations are not characteristic of osteogenic sarcoma alone. In this small series we have seen them in chondrosarcoma, periostitis and metastatic carcinoma. In the latter case the carcinoma was primary in the prostate gland. Bone metastases from prostatic carcinoma as well as from some carcinomas of the gastrointestinal tract and benign hemangiomas of bone may show the perpendicular striations.

We have made an effort to differentiate the type of spicules produced by osteogenic sarcoma and chondrosarcoma and have included illustrations of each type. However, the striations produced in Case 25*, that of traumatic periostitis, are quite similar to those of osteogenic sarcoma, and to us it appears impossible to distinguish between these two roentgenologically or clinically. This appearance can be produced by any injury in which the periosteum is elevated and there is hemorrhage beneath it but where some of the vertically arranged blood vessels remain intact, as is the case when bone is operated upon. Therefore, care must be exercised in the interpretation of the significance of perpendicular spicules surrounding bone observed in roentgenograms obtained a week to ten days following operation.

* See footnote to Case 25.

FIG. 21. Case 26. Hemangioma of bone showing a localized area of expansion of the cortex with destruction, which might be mistaken for osteolytic osteogenic sarcoma.

Cases 19, 20, and 21 illustrate the difficulties developing from the fact that some cases of osteogenic sarcoma have roentgen patterns typical of chondrosarcoma, and vice versa. The case of Ewing's tumor presented as Case 22 could easily be confused with chondrosarcoma. Swenson[22] has recently stated that the only characteristic feature of Ewing's tumor was destruction of bone, which all cases exhibit, but that there was no pathognomonic feature. This supports the contention that before radical surgical treatment is instituted, biopsy should be done,[17] and we believe that if clinical and roentgen examinations do not show an unequivocal malignant bone tumor the pathologist should have the benefit of the best possible sections instead of having to rely on a frozen section. If frozen section is done and the findings are in the slightest degree equivocal, then the surgeon should wait until good paraffin sections can be

made and studied. In Case 24 a leg was sacrificed because of an error in diagnosis on frozen section, and a too hasty procedure might have had the same result in Case 25. An arm might have been needlessly amputated in Case 26 if the surgeon had not been sure enough that he was dealing with a benign tumor from the gross appearance.

The need for a skeletal survey in all cases of suspicious bone lesion is illustrated by Cases 18 and 23. The former was called metastatic carcinoma at the first examination, but if a survey had been done and no other lesion found and if a careful clinical and roentgenologic search had been carried out for the primary site and none found, the diagnosis of primary bone neoplasm possibly would have been reached sooner. In the latter case a skeletal survey would have revealed other metastatic foci. We do not mean to infer that all metastatic tumors are multiple or that the primary growth can be found in all cases, although that is often true, as it was in Case 23.

CLINICAL COURSE

It is obvious that 9 cases of any disease is not a sufficiently large series from which to derive any percentage statistics as to methods of treatment, but from our 7 cases of typical osteogenic sarcoma and 2 cases which were diagnosed pathologically as osteogenic sarcoma but considered roentgenologically to represent other groups, all are dead, the longest survival being twenty-nine months in Case 20, one of the atypical group. With the exception of Cases 2, 5, and 6 all of these patients had immediate amputation or excision of the tumor. Case 2 had a delay of three months in which he was given a moderate amount of irradiation. Case 5 had a delay of two months in an attempt to give irradiation, but since it was not well tolerated only a very small amount was given, and Case 6 had irradiation for one month. While this is the type of treatment recommended by both Ferguson[7] and McNattin,[15] in none of these cases did the delay approach the time period they advocate and the quantity of irradiation in each case was much less than that recommended by the latter. According to Ferguson's criteria, the treatment in all our cases of osteogenic sarcoma comes under the heading of immediate amputation.

Of these 9 cases, all of whom had "immediate" amputation, all are dead, 8 dying with metastases and the ninth (Case 21) immediately following amputation in another hospital. Two of these patients were aged forty years; 1 had a tumor of the scapula (Case 5); the other had a tumor of the femur and is listed with the atypical cases (Case 19). The ages of the others ranged from thirteen to twenty. As we have mentioned this is a small series, but it indicates that immediate amputation was not the answer to the problem of treatment in these patients. While we have no patients in whom amputation was delayed more than three months, the results reported by McNattin[15] are far superior to those we can show.

The results at Memorial Hospital in New York with preoperative irradiation are not as striking, but Coley and Pool[3] report 34 per cent five year survival with irradiation followed by radical surgical treatment as opposed to 31 per cent with radical surgery alone.[9] However, they did not use as heavy dosage nor delay for as long a time as McNattin.[15] Coley and Pool's cases include chondrosarcomas and periosteal fibrosarcoma and McNattin includes at least one fibrochondrosarcoma.

Ferguson[7] has amply discussed the possible reasons for the improved end-results associated with delayed amputation. Coley and Pool's figures support Ferguson's principal thesis but they disagree with him in considering that the length of delay corresponds with the relative degree of malignancy. Specifically, they agree with Copeland[1] that the tumors of lower grades of malignancy are those in which treatment is long delayed.

Whereas our results with early amputation in osteogenic sarcoma are uniformly bad, this is not true of the chondrosarcomas. In our group of 11 cases of chondro-

sarcoma and 1 doubtful case, all with complete follow-up, 4 are alive and without evidence of disease at the time of this report. Two of these cases (Cases 10 and 11) have been treated too recently for evaluation (one year and three months, respectively). The other 2 cases have survived eight and six years (Cases 8 and 9). These 4 cases were treated surgically, the 2 with long survivals by amputation and the 2 with short survivals, both tumors of ribs, by resection. In 2 of the remaining 8 cases, there was no attempt at treatment other than biopsy and 1 other patient received irradiation and Coley's toxin, but no radical surgical treatment (Case 12). The remaining 5 patients were treated surgically, either by amputation or excision. In all of the treated fatal cases metastases occurred within a year after the initial treatment of the lesion. Although the percentage of survivals means little in a series so small, it seems significant that all of our living patients with malignant bone tumors, including 2 patients surviving six and eight years, had chondrosarcoma.

The tumor of one of our long surviving cases is probably secondary to a pre-existing enchondroma, and this may also be true of the 2 cases of rib tumor recently treated. Among the patients who failed to survive, 2 had chondrosarcomas developing in the cartilaginous cap of osteochondromas and 1 had chondrosarcoma secondary to localized Paget's disease of bone, With one exception (Case 9), these secondary chondrosarcomas occurred in individuals past the age of thirty. One apparently primary chondrosarcoma occurred in a patient aged thirty-six and one in a patient over fifty years of age (Case 18).

SUMMARY

A series of cases of osteogenic sarcoma, chondrosarcoma and other bone lesions seen in the Hospital of the University of Pennsylvania since January 1, 1931, has been reviewed. There were 7 cases of osteogenic sarcoma, 11 cases of chondrosarcoma, and 3 cases in which the roentgen and pathologic diagnoses were at variance. We have also included 5 cases which might be confused with these conditions. There is a characteristic roentgen pattern for each of these groups, but enough cases differ from this to make us feel that the diagnosis cannot be made from the roentgen examination alone. As benign conditions may simulate malignant tumors the pathologist should have the best possible material on which to base his diagnosis. Every case presenting a bone lesion of this type should have a roentgen survey of the skeletal system to determine the presence of other lesions.

All of the patients with osteogenic sarcoma were treated by immediate amputation and all died, the longest survival being twenty-nine months. Four cases of chondrosarcoma survive, one for eight years and one for six years. The other 2 cases were treated within the last fifteen months. Because of the differences in clinical course and survival rate, we are in agreement that these two groups of tumors should be separated, as recommended by the Bone Tumor Registry of the American College of Surgeons.

CONCLUSIONS

1. The diagnosis of the pathologic type of malignant bone tumor cannot be made with certainty from the roentgen examination alone.

2. Benign conditions may simulate malignant bone tumors.

3. In order to make as many correct diagnoses as possible, one should do a complete skeletal survey in every case of bone lesion which is suspected of being malignant, and the material submitted to the pathologist as a biopsy should be representative of the tumor. He should be allowed adequate time to make and study paraffin sections if there is any doubt about the nature of the lesion.

4. The problem of treatment of malignant bone tumors in general and of osteogenic sarcoma in particular has not been solved.

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REFERENCES

1. Brailsford, J. F. Radiological evidence of malignancy in bone tumors, and its relation to biopsy. *Radiology*, 1939, *33*, 476–496.
2. Copeland, M. M. Bone tumors with reference to their treatment. *Surgery*, 1942, *11*, 436–455.
3. Coley, B. L., and Pool, J. L. Factors influencing the prognosis in osteogenic sarcoma. *Ann. Surg.*, 1940, *112*, 1114–1128.
4. Codman, E. A. Registry of bone sarcoma. *Surg., Gynec. & Obst.*, 1926, *42*, 381–393.
5. Ewing, J. Review of the classification of bone tumors. *Surg., Gynec. & Obst.*, 1939, *68*, 971–976.
6. Ewing, J. Neoplastic Diseases. Fourth edition. W. B. Saunders Co., Philadelphia, 1940.
7. Ferguson, A. B. Treatment of osteogenic sarcoma. *J. Bone & Joint Surg.*, 1940, *22*, 92–96.
8. Geschickter, C. F., and Copeland, M. M. Tumors of Bone. American Journal of Cancer, New York, 1931.
9. Higinbotham, N. L., and Coley, B. L. Methods and effects of preoperative irradiation in the treatment of osteogenic sarcoma. Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 902–908.
10. Howes, W. E., and Schenck, S. G. Roentgenologic considerations in diagnosis and treatment of primary malignant bone tumors. *Radiology*, 1941, *37*, 18–34.
11. Lichtenstein, L., and Jaffe, H. L. Chondrosarcoma of bone. *Am. J. Path.*, 1943, *19*, 553–589.
12. Luck, J. V. Correlation of roentgenogram and pathological changes in ossifying and chondrifying primary osteogenic neoplasms. *Radiology*, 1943, *40*, 253–275.
13. Kolodny, A. Bone sarcoma; primary malignant tumors of bone and giant cell tumor. *Surg. Gynec. & Obst.*, 1927, *44*, 1–214.
14. MacDonald, I., and Budd, J. W. Osteogenic sarcoma. I. A modified nomenclature and a review of 118 five year cures. *Surg., Gynec. & Obst.*, 1943, *77*, 413–421.
15. McNattin, R. F. Treatment of osteogenic sarcoma with preoperative roentgen radiation in large doses. *Radiology*, 1944, *42*, 246–248.
16. Meydering, H. W. Classification of bone tumors. *Proc. Staff Meet., Mayo Clin.*, 1943, *18*, 17–18.
17. Meyerding, H. W., and Valls, J. E. Primary malignant tumors of bone. *J. Am. M. Ass.*, 1941, *117*, 237–243.
18. Murphy, J. T. Discussion of McNattin.[15]
19. Phemister, D. B. Chondrosaroma of bone. *Surg., Gynec. & Obst.*, 1930, *50*, 216–233.
20. Simmons, C. C. Bone sarcoma; factors influencing prognosis. *Surg., Gynec. & Obst.*, 1939, *68*, 67–75.
21. Singleton, A. C. Sources of error in radiological interpretation in tumors of bone. *Radiology*, 1937, *29*, 83–88.
22. Swenson, P. C. Roentgenologic aspects of Ewing's tumor of bone marrow. Am. J. Roentgen. & Rad. Therapy, 1943, *50*, 343–354.

TERATOMA OF THE TESTIS

REPORT OF SIXTY-FIVE CASES*

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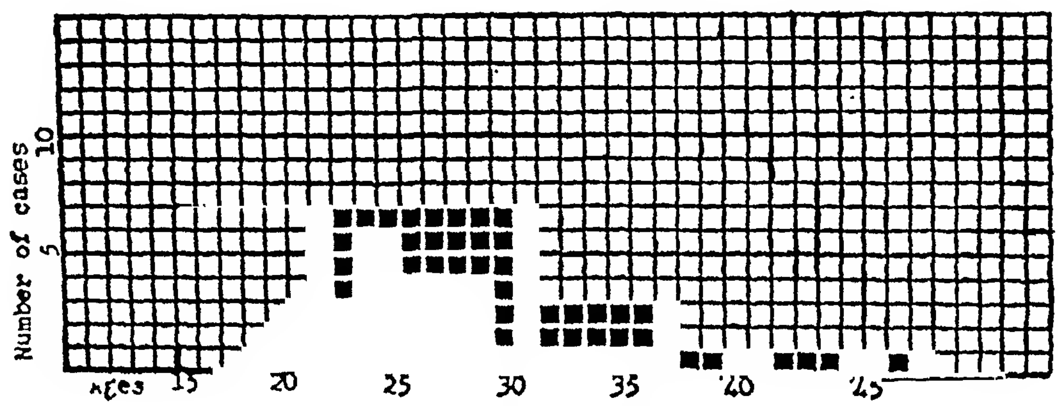
SIXTY-FIVE cases of teratoma of the testis have been observed and treated within the past thirty-three months at an Army general hospital. This is a percentage of 0.315 for hospital admissions, 2.62 per cent for all cases admitted to the Genitourinary Service and 7.86 per cent for all cases of malignancy. This frequency is relatively high, and constitutes one of the more common class of tumors observed. It has been pointed out that for the year 1941, 7.2 per cent of all malignant neoplasms occurring in white personnel of the Army were testicular tumors,[1] and this is emphasized by our findings.

These tumors have been reported as occurring most frequently between the ages of twenty and forty years, although patients as old as eighty-four years[2] and infants as young as nine months[3] have been known to suffer from the condition. The average age of the 65 cases was twenty-eight years and is within the mean reports of other authors. The distribution of incidence is shown in Figure 1.

The average occurrence ages for the various types of tumors is given in Table I.

The etiology of these malignant tumors of the testis is not fully known but it is felt that the various factors which should be considered are heredity, abnormal development, sexual activity, trauma, occupation, biochemical or endocrine changes, and infections. Of these the most significant is probably abnormal development, especially ectopic or undescended testes, which was present in only 3 of the cases observed.

Another factor to be considered is that of trauma, which was mentioned in the history of 21 cases, but whether the trauma in any case produced the tumor can be disputed, for it seems more apparent that the trauma in almost every instance called the



AGE INCIDENCE

Fig. 1

Table I

AVERAGE OCCURRENCE AGES FOR THE VARIOUS TYPES OF TUMORS

	Age yr.
Adult teratoma	27
Teratoid (mixed)	
Rhabdomyosarcoma	20
Adult malignant	40
Embryonal	
Adenocarcinoma	26.4
Embryonal carcinoma	29.9
Fibroma	25

* Presented at the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, Chicago, Ill., Sept. 24–29, 1944.

patient's attention to the presence of the mass.

The necessity for an early diagnosis in testicular tumors cannot be overstressed. Of the 65 cases treated there were 27, or 41.5 per cent, who were treated for conditions other than teratoma before the final diagnosis was suspected. These conditions, together with the number of cases of each, are given in Table II.

Table II

Epididymitis	8
Orchitis	7
Hydrocele	6
Hematocele	2
Abdominal mass (with operation and the diagnosis suspected from the pathological report)	3
Syphilis and gonorrhea (when the enlarged testicle was noted during the course of treatment)	1

Early diagnosis can generally be made if one remembers the most important features of the symptoms and signs. It must be recalled that the development of these tumors is usually insidious and that the patient is not aware of the condition until it has existed for some time. By far the most frequent symptom is painless swelling, which was the case with 45 patients (69 per cent) of this series. Pain is a less common symptom and when present may be the result of coincidental trauma, sudden growth or extension outside the confines of the tunica. This symptom was noted in 14 cases (21.5 per cent). In 6 cases (9 per cent) the tumor was found on routine examinations for other purposes, but these patients recalled the sensation of a heaviness or dragging sensation within the scrotum. Symptoms referable to masses within the abdomen or adenopathy are indicative of far advanced growth and should not be considered in the discussion of early diagnosis.

The duration of symptoms before the patient seeks medical attention is difficult to explain, especially since the organs are so prominently situated. Procrastination on the part of the patient to submit to examination when he believes there might be a tumor is a handicap that can only be overcome through medical education. This observation is present among the cases of this series, but is not so obvious as among similar cases in civilian practice, probably because of the periodic and routine physical examinations conducted for the control of diseases among the Armed Forces. Of the 65 cases, 75.21 per cent received medical attention within the first year after the symptoms were noted, and of these, 12.33 per cent were of one month's duration or less; 7.69 per cent were of two months'; 9.07 per cent three months'; 10.76 per cent four months'; 1.53 per cent five months'; and 7.69 per cent were of six months' duration.

The diagnostic signs of these tumors are few but significant and important. The history and course of the condition may be suggestive—usually a progressive enlargement of the testicle, sometimes with pain but more frequently without pain. The testicular tumor generally involves the testis by infiltration and invasion rather than by displacement, so that there is a tendency for the organ to retain its natural outline. The testis is usually smooth and freely movable, and it is not until the advanced stages of growth that it may show signs of being nodular or irregular and fixed. A fixed mass may be accepted as one escaping its natural confines, and in these cases the scrotum is usually involved and there is evidence of inguinal adenopathy. Early in the development of the tumor the testicle is quite firm to stony hard, though cystic areas are not uncommon, probably due to the rapid growth with the areas of focal necrosis. Neuralgia or tenderness on examination is not uncommon. The cord may be thickened because of the increased weight, resulting in some engorgement of the vessels, but in nearly every case the epididymis can be delineated. The mass does not transilluminate light.

Differentiation must often be made from epididymitis, hydrocele, hematocele, gumma, tuberculous orchitis, or a chronic orchitis with fibrosis from other causes. Careful examination and routine clinical and laboratory studies can usually differentiate these conditions at an early date.

In those cases which offer any question of diagnosis, we believe a surgical exploration is warranted rather than aspiration of the mass or delay for observation while the patient is under palliative treatment.

Of our series, 34 cases (52.3 per cent) had involvement of the right side, 29 cases (44.6 per cent) were on the left side, and 2 cases (3.07 per cent) were bilateral. This same degree of difference is noted by other authors and is explained on the basis of a greater frequency of undescended testis on the right side.[4]

Any attempt at classification in this brief presentation would be inadequate. It is only necessary to point out that we feel most present day classifications are inadequate. Both Ewing's classification and that of the Army Medical Museum have been used as a working basis.

In reporting our results, we believe at this time that for all purposes, it is best to list the number of each type found pathologically according to these two classifications. This is shown in Table III.

The treatment generally practiced at our hospital for these tumors is one of combined surgery and irradiation. Here, we believe, lies the second most important factor for the patient's best chance of survival, namely, early adequate operation, followed by sufficient irradiation, the first and most important factor being early recognition. By early adequate operation is meant that when a testicular mass is suspected or clinically diagnosed as being a tumor, the patient undergoes an orchidectomy and removal of the cord with accompanying structures high at the internal abdominal ring. We believe this operation of high removal is always indicated for two reasons: namely, the removal of as much of the lymphatic tract as possible, and the comfort of the patient. So often the remaining stub of the cord is not only a potential site for recurrences but is also tender and a constant source of irritation and discomfort which leads to future complaints.

Table III

COMPARATIVE TABLES

Ewing's Classification	
1. Adult embryoma or teratoma	2
2. Embryoid, teratoid or mixed tumors.	
(a) Rhabdomyosarcoma	1
(b) Adult malignant teratoma	1
3. Embryonal malignant tumors	
(a) Adenocarcinoma	28
(b) Embryonal carcinoma	33
(c) Seminoma	0
4. Others	
(a) Fibroma	1

Army Medical Museum Classification	
1. Teratoma benign	3
2. Teratoma malignant	
(a) Embryonal carcinoma	33
(b) Adenocarcinoma	28
(c) Seminoma	0
(d) Non-epithelial tumors	
(1) Rhabdomyosarcoma	1
(2) Fibroma	1

As soon as it is felt advisable to move the patient after operation, as early as the third to fifth day, a course of external deep roentgen therapy is begun.

Therapy is given with the following factors: 220 kv. (G. E. Maximar), 15 ma., 50 cm. target-skin distance, 0.5 to 1.0 mm. Cu plus 1.0 mm. Al filter (half-value layer, 0.9–1.35 mm. Cu), 47 to 32 r per minute (measured in air).

The course of irradiation, as given here in all our cases, depends upon (1) those cases in which no metastases are found at any time, and/or in which the duration of symptoms is six months or less; and (2) the presence of metastases before operation or before treatment, and on duration of symptoms over six months.

In those cases falling within group (1) of no metastases, the portals of treatment are

directed over the operative site (including the scrotum and femoral triangle), over the mid-abdomen, epigastrium, and posteriorly over the upper sacrum and abdomen, and flanks (Fig. 2).

Those cases in which metastases are suspected or are known to be present, group

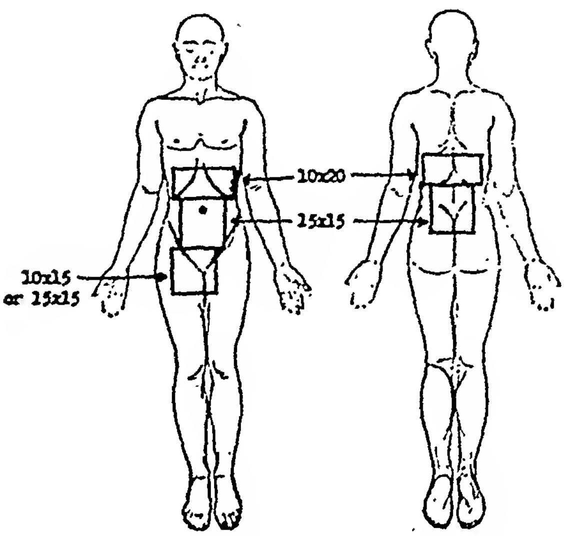


FIG. 2. Patient without metastases.

(2), the fields are the same as those used in group (1) with the addition of a lateral field to the abdomen, anterior and posterior

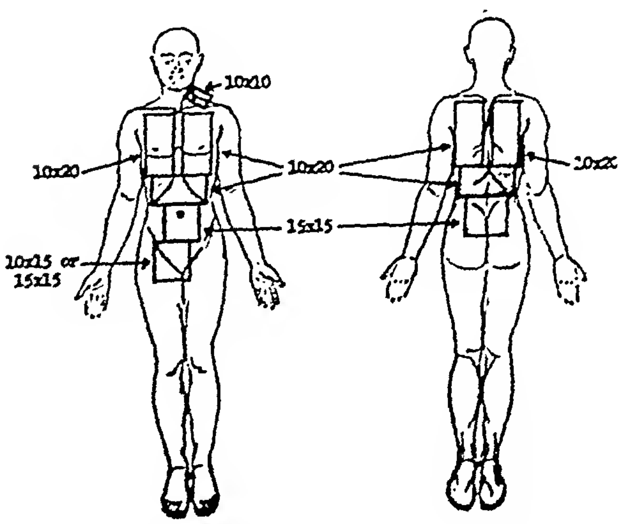


FIG. 3. Patient with known metastases.

chest fields, and usually another field over the left supraclavicular region (Fig. 3).

In both outlines of treatment, the daily amounts of radiation (no treatments given on Sunday) are 200 to 250 r to each of two fields, in rotation, until a total of 1,600 to 2,000 r per field has been administered.

The most frequent complication of treatment is irradiation sickness. Another factor observed is the patient's general constitutional toleration first evidenced probably by signs of leukopenia. The complications are all treated by more or less conventional methods, based upon supportive care.

Upon completion of treatments all patients are carefully checked for evidences of metastases or recurrences, and when maximum hospitalization has been reached each case is presented for disposition.

The most earnest attempts are made to follow these patients. This is often done directly between the patient's referred or family physician, veterans' facilities, or the information is obtained from the patient

Dear Sir:

I would appreciate hearing from you on your present condition. It is necessary that I have a follow up on cases treated that others in the future might be benefited from any information you can give me.

1. Have you maintained your weight?
2. Do you have any complaints—(cough, pain, enlarged glands)? If yes, please explain.
3. Has there been any recurrence of tanning at the spots where you received X-Ray Therapy?
4. Do you have any difficulty in elimination?
5. Are you receiving frequent check-up examinations? If yes, please give the name and address of your physician.

Sincerely,

Major, M. C.

P.S.—You may use this sheet for reply.

FIG. 4

himself through correspondence with a form letter (Fig. 4).

To the best of our knowledge, we have had only 7 deaths in the last thirty-three months among the 65 cases treated. A like number are returning for additional roentgen therapy or inform us of complaints varying all the way from loss of weight, cough, and weakness to vague abdominal symptoms. The majority of these patients are apparently well and have returned to a wage-earning civilian life.

SUMMARY

1. Sixty-five cases of teratoma of the testis have been followed within the past thirty-three months. They were found to occur in individuals at the average age of twenty-eight years.

2. Early diagnosis is the most important factor in a high survival rate and cannot be overstressed. Of the cases, 75.21 per cent received medical attention within the first year after the symptoms were noted.

3. The most important diagnostic sign is painless swelling of the testicle with a tendency for the organ to retain its natural shape and outline.

4. Treatment should be early and adequate, relying upon surgery and postoperative irradiation. Surgery includes not only an orchidectomy but removal of the cord high at the internal abdominal ring.

5. Irradiation is given early postoperatively and is outlined depending upon the duration of symptoms and presence of demonstrable metastases.

6. Follow-up shows that 72.3 per cent of these 65 cases have replied to correspondence; 10.7 per cent of the total number of cases have died.

CONCLUSION

It is believed that this plan of treatment, orchidectomy with postoperative irradiation, is superior to orchidectomy or irradiation alone.

REFERENCES

1. *Bull. U. S. Army Med. Dept.*, 1944, p. 34.
2. Cabot, H., and Berkson, J. Neoplasms of the testis; study of results of orchidectomy, with and without irradiation. *New England J. Med.*, 1939, *220*, 192–195.
3. Dean, A. L., Jr. Teratoid tumors of the testis. *J. Am. M. Ass.*, 1935, *105*, 1965–1971.
4. Eisendrath, D. N., and Rolnick, H. C. Urology. Fourth edition. J. B. Lippincott Co., Philadelphia, 1938.

DISCUSSION

Dr. Walter C. Popp, Rochester, Minn. I wish to congratulate Major Barner for his excellent paper on teratoma of the testis. He has emphasized the necessity of early diagnosis and has pointed out the possibility of incorrect diagnosis and the inadequacy of present classifications of testicular tumors. I think all of us have difficulty in trying to place the various testicular tumors in certain categories.

At the Mayo Clinic we use as a working basis a rather simplified classification of tumors of the testis which seems to be workable from a clinical standpoint. This classification briefly consists of

1. Seminoma or adenocarcinoma of Chevassu, grade 4;
2. Adenocarcinoma, grades 1 to 4;
3. Teratoma;
4. Mixed seminoma and teratoma, and
5. Unusual testicular tumors such as fibrosarcoma.

Our statistics are based on results in the individual groups, and the range of sensitivity to irradiation is in keeping with the pathologic classification. In other words, seminoma is most sensitive; adenocarcinoma moderately sensitive; and teratoma, and mixed seminoma and teratoma are least radiosensitive.

The general plan of treatment recommended by Major Barner is much the same as that which we follow in the handling of testicular tumors. There are two exceptions to his general plan. First, we irradiate the abdomen through four anterior and four corresponding posterior fields, the mediastinum through anterior and posterior fields and the left supraclavicular region through one field. These fields are used regardless of whether metastatic involvement is found. Second, we use voltages in the range of 130 kv. rather than in the range of 200 kv.

As Major Barner has pointed out, the possibility of cure is greater in those cases of testicular tumor in which early diagnosis and surgical removal are followed by thorough roentgen treatment as soon as feasible after operation.

ATYPICAL ESOPHAGEAL DISPLACEMENT WITH LEFT ATRIAL DILATATION*

WITH NOTES ON RHEUMATIC AORTITIS

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VISUALIZATION of the esophagus with barium paste is necessary for examining the left atrium and the aorta in cardiac roentgenoscopy. Normally the barium-filled esophagus appears as a straight tube behind the trachea, indented on its left anterolateral aspect by the transverse thoracic aorta and immediately beneath by the left main bronchus and the pulmonary artery. The aortic indentation in the esophagus is called the "aortic bed," and the normal diameter of the transverse thoracic aorta at this level is approximately 3 cm. The esophagus then proceeds straight down, sloping slightly forward and to the left in front of the descending thoracic aorta and behind the left atrium to the diaphragmatic hiatus. Usually the lowermost part of the left atrium cannot be differentiated roentgenologically from the subjacent small portion of the right atrium. The esophagus maintains its relationship to the aorta by its adventitial coat of loose areolar fibrous tissue which merges with the aortic adventitia.

By far the most common cause of left atrial enlargement is mitral valve disease. Left atrial enlargement usually produces an impression in the esophagus which roughly parallels the degree of its dilatation. The first manifestation may be but a slight concavity in the esophagus visible only in the right anterior oblique projection. This may precede any change in the frontal projection of either the heart or the esophagus.[3] As enlargement progresses the arcuate impression in the barium-filled esophagus increases, concomitant with deviation of the esophagus towards the right in the later stages. By this time teleroentgenographic examination may show the classical changes in the heart contour associated with mitral valve disease.

The roentgenologic appearance of the esophagus due to left atrial enlargement seen in the right anterior oblique projection may be simulated by the esophageal displacement due to aortitis accompanying hypertension and arteriosclerosis in elderly individuals. This occurs when there is sufficient elongation and tortuosity of the aorta and is best demonstrated in patients with kyphosis of the thoracic spine. Schwedel[14] pointed out that a diagnosis of left atrial enlargement should not be made in these patients without first examining them in the posteroanterior and left anterior oblique positions. If the esophageal displacement is due to aortitis the curvature will be to the left and posteriorly, closely following the transverse and descending thoracic aorta, while left atrial dilatation shifts the esophagus posteriorly and towards the right.

Rigler[13] also mentioned the effect of aortitis on the position of the esophagus and discussed its application to the diagnosis of aortic aneurysm. We have repeatedly confirmed his observations as to the displacement of the esophagus by aneurysms of the transverse and descending thoracic aorta, and have also noted that in some patients with relatively early syphilitic aortitis lacking convincing change in the frontal configuration of the aortic arch there may be a deepening of the aortic bed by the slight posterior displacement of the esophagus as it passes the transverse thoracic aorta. This may be confirmed by examination in the left anterior oblique position, which shows apposition of the esophagus to the posterior inferior portion of the trans-

* From the Roentgenologic Service of M. G. Wasch, M.D., The Jewish Hospital of Brooklyn, Brooklyn, N. Y.

verse thoracic aorta. The reason for this change we believe may be syphilitic aortitis resulting in aortic-eosphageal adhesions. We regard this observation as a possible aid in the diagnosis of early syphilitic aortitis, and worthy of further study. As a rule, the amount of esophageal displacement with syphilitic aortitis is insufficient to present any difficulty in the differential diagnosis of left atrial dilatation.[15]

One etiologic agent which may result in aortitis in children and adolescents as well as in adults is rheumatism. Rheumatic aortitis was first clearly described by Klotz[7] and was further investigated by Pappenheimer and VonGlahn[10] and by Gross.[5] Boyd[1] commented that there was little doubt that rheumatic aortitis occurred in nearly every if not every case of rheumatic heart disease. Changes due to rheumatism have also been described in the coronary and pulmonary arteries and the peripheral circulation.[4,6]

As a rule, the histopathologic changes from rheumatic aortitis are less marked than those associated with other forms of aortitis. Gross inspection of the organs may show only slight changes, but microscopically a well marked picture frequently presents itself. Flame-shaped scars have been described as common in the media, particularly about the nutrient vessels. These cicatrices are dense and acellular and have been interpreted as healed or healing lesions. Aschoff bodies and isolated Aschoff cells have been identified in the adventitia and the media.[9] Intimal changes comparable to those described in the left atrial endocardium by MacCallum[8] have been reported by Pappenheimer and VonGlahn. These consist of small, glistening, translucent ridges or plaques, either round or oval in shape, which are pale brown in contrast to the dull, opaque orange-yellow atheromatous lesions or the gray, glistening, wrinkled plaques of syphilitic aortitis. In arrangement and staining reaction the cells which form the plaques are identical with those so characteristically present in the atrium. The medial lesions encountered under the plaques are diffuse. The most striking change is a complete loss of muscle cells over large areas so that only the collagen and elastic fibers persist. Actual rupture or fragmentation may be seen in places. Towards the outer third of the media perivascular lesions having the characteristics of Aschoff bodies may be present.[12] In the adventitia a diffuse increase in the connective tissue has been described with hyalinization, thickening of the walls of the small arteries and arterioles and eccentric thickening of the veins.[2] Acute inflammatory changes have also been reported in the adventitia.[11]

No mention is made of aortic-esophageal adhesions in the reports reviewed. Nevertheless, the presence of an inflammatory reaction in the adventitia indicates the probability of such adhesions. In this way rheumatic aortitis when sufficiently extensive may result in the same aortic-esophageal adhesions as occur with hypertensive, arteriosclerotic or syphilitic aortitis. In the event that these adhesions are sufficiently strong before left atrial enlargement takes place, it might be anticipated that subsequent dilatation of that chamber would not deviate the esophagus in the usual manner. This, then, would be one circumstance in which left atrial enlargement would not be accompanied by the expected displacement of the esophagus posteriorly and to the right.

During the past eight years we have encountered 6 patients with rheumatic mitral and aortic valve disease who had left atrial enlargement of an advanced degree without the expected pattern of esophageal deviation. During this time over 3,000 patients were examined roentgenoscopically, and approximately one-third of them had organic heart disease. Roentgenoscopically and roentgenographically there was no doubt as to the posterior bulge of the left atrium and its approach to the right cardiac border. The barium-filled esophagus was displaced posteriorly and to the left in the 6 patients reported here, so that its shadow in the right anterior oblique position pre-

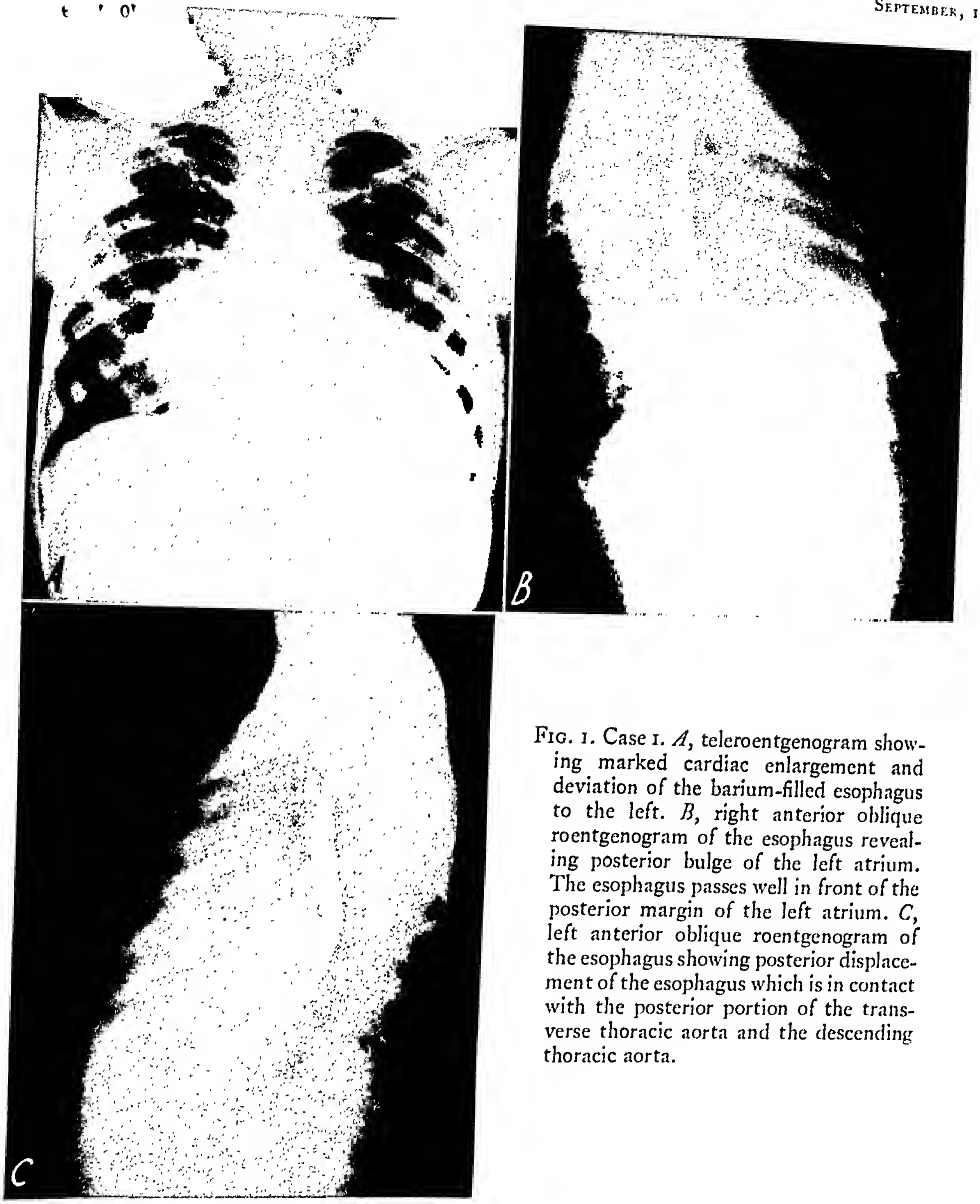

Fig. 1. Case 1. *A*, teleroentgenogram showing marked cardiac enlargement and deviation of the barium-filled esophagus to the left. *B*, right anterior oblique roentgenogram of the esophagus revealing posterior bulge of the left atrium. The esophagus passes well in front of the posterior margin of the left atrium. *C*, left anterior oblique roentgenogram of the esophagus showing posterior displacement of the esophagus which is in contact with the posterior portion of the transverse thoracic aorta and the descending thoracic aorta.

sented as a relatively straight line passing well in front of the left atrial bulge.

The youth and clinical history of 3 of these eliminated hypertension, arteriosclerosis or syphilis as the etiologic factor for the aortic-esophageal adhesions. The remaining 3 were adults who presented classical pictures of advanced rheumatic heart disease with mitral and aortic valve involvement.

REPORT OF CASES

Case 1. G. Y., male, aged ten, had rheumatic fever at the age of five years. Cardiac involvement appeared one year later. Since then he has had several episodes of rheumatic activity with congestive heart failure requiring prolonged bed rest and diuretics. There were frequent brief attacks of precordial pain and orthopnea. His activity had to be markedly restricted at all times.

Physical examination revealed the heart to be enlarged to the left. The heart sounds were rapid, of fair quality, and regular. Blowing systolic and diastolic murmurs were present over the entire precordium. Blood pressure was 115/0. The radial pulse was of the Corrigan type and pistol-shot sounds were heard over the femoral arteries. Electrocardiographic examination revealed the auriculoventricular conduction time to be 0.22 second.

Roentgenoscopic and roentgenographic examination of the chest showed considerable cardiac enlargement with straightening of the pulmonary artery and conus segment of the left heart border. The aortic knob was inconspicuous, but the aortic pulsations were increased in amplitude. The left ventricle was enlarged downward, posteriorly and to the left. Considerable anterior prominence of the right ventricle was present.

The barium-filled esophagus was drawn posteriorly and to the left as seen in the anteroposterior and left anterior oblique views. In the right anterior oblique position there was a marked posterior bulge of the left atrium. The barium-filled esophagus passed in front of the left atrial bulge as a relatively straight line.

Comment. Even though there was marked left atrial dilatation the barium-filled esophagus was shifted posteriorly and to the left, closely following the transverse and descending thoracic aorta. The most satisfactory explanation for the atypical position of the esophagus in this case would be the presence of rheumatic aortic-esophageal adhesions which prevented the expected esophageal displacement.

Case II. S. B., male, aged nine, had rheumatic fever at the age of four years. An apical systolic murmur transmitted to the axilla was heard at that time, and prolongation of the auriculoventricular conduction time to 0.22 second was found on electrocardiographic examination. One year later he had a second episode with joint pains, epistaxis and precordial pain. Double mitral and aortic murmurs were heard at that time. He required hospitalization for about eight months. One year after his discharge he was again hospitalized because of episgastric pain, precordial pain, vomiting, fever and increasing pallor. Classical findings of double mitral and aortic valve disease were found on examination. The blood pressure then was 110/50.

Roentgenoscopic and roentgenographic examination of the chest revealed marked enlargement of the left ventricle downward and posteriorly. The right ventricle was enlarged anteriorly. The pulmonary artery and conus arc of the left heart border was convex, and the aortic knob was small. The left atrium was markedly enlarged posteriorly, and protruded far into the posterior mediastinum as seen in the right anterior oblique position. On an overpenetrated posteroanterior teleroentgenogram, the left atrium could be seen close to the right heart border. The barium-filled esophagus was displaced to the left and posteriorly in close proximity to the aorta, and in the right anterior oblique position was seen to pass well in front of the bulge of the left atrium. The pulsations of the heart and aorta were exaggerated, and the increased amplitude of pulsation was reflected in the motions of the esophagus observed roentgenoscopically.

Comment. The atypical position of the esophagus in the presence of advanced left atrial dilatation may best be ascribed to the presence of rheumatic aortitis and aortic-esophageal adhesions.

Case III. H. B., male, aged seventeen, first had rheumatic fever at the age of eleven years, with migratory joint pains, followed by dyspnea, palpitation, fever and precordial pain. He required hospitalization for several months and following this was able to get about with moderate restriction of activity.

Physical examination revealed a heaving apical impulse in the sixth left intercostal space in the anterior axillary line. Loud blowing systolic and diastolic murmurs were heard over the apex and base of the heart. The blood pressure was 160/80.

Roentgenoscopic and roentgenographic examination of the heart revealed advanced cardiac enlargement with straightening of the left cardiac border. The left atrium was markedly dilated, protruding far into the posterior mediastinum and extending toward the right to form the upper two-thirds of the right heart border. The barium-filled esophagus was shifted to the left and posteriorly in close proximity to the aorta. The aortic knob was small, but its activity observed roentgenoscopically was hectic and the motion was transmitted to the

Fig. 2. Case ii. *A*, overexposed teleroentgenogram revealing marked enlargement of the heart. The upper two-thirds of the right heart border is formed by the left atrium. The barium-filled esophagus is drawn to the left. *B*, right anterior oblique roentgenogram of the esophagus. The esophagus passes in front of the bulge of the enlarged left atrium. *C*, left anterior oblique roentgenogram showing posterior displacement of the esophagus.

esophagus. There was elevation and slight compression of the left main bronchus.

Comment. The atypical position of the esophagus in the presence of advanced left atrial dilatation suggests the presence of aortic-esophageal adhesions.

Case iv. R. W., female, aged thirty-four, first had rheumatic fever at the age of twenty-four, and was informed of cardiac involvement four years later. Since then she has become progressively more dyspneic and has had several episodes of congestive heart failure. At first these were mild and responded readily to bed rest and digitalis. Later mercurial diuretics were required. She was admitted to the hospital in acute decompensation. The blood Wassermann reaction was negative.

Physical examination revealed the heart to be enlarged to the left. Long, loud blowing

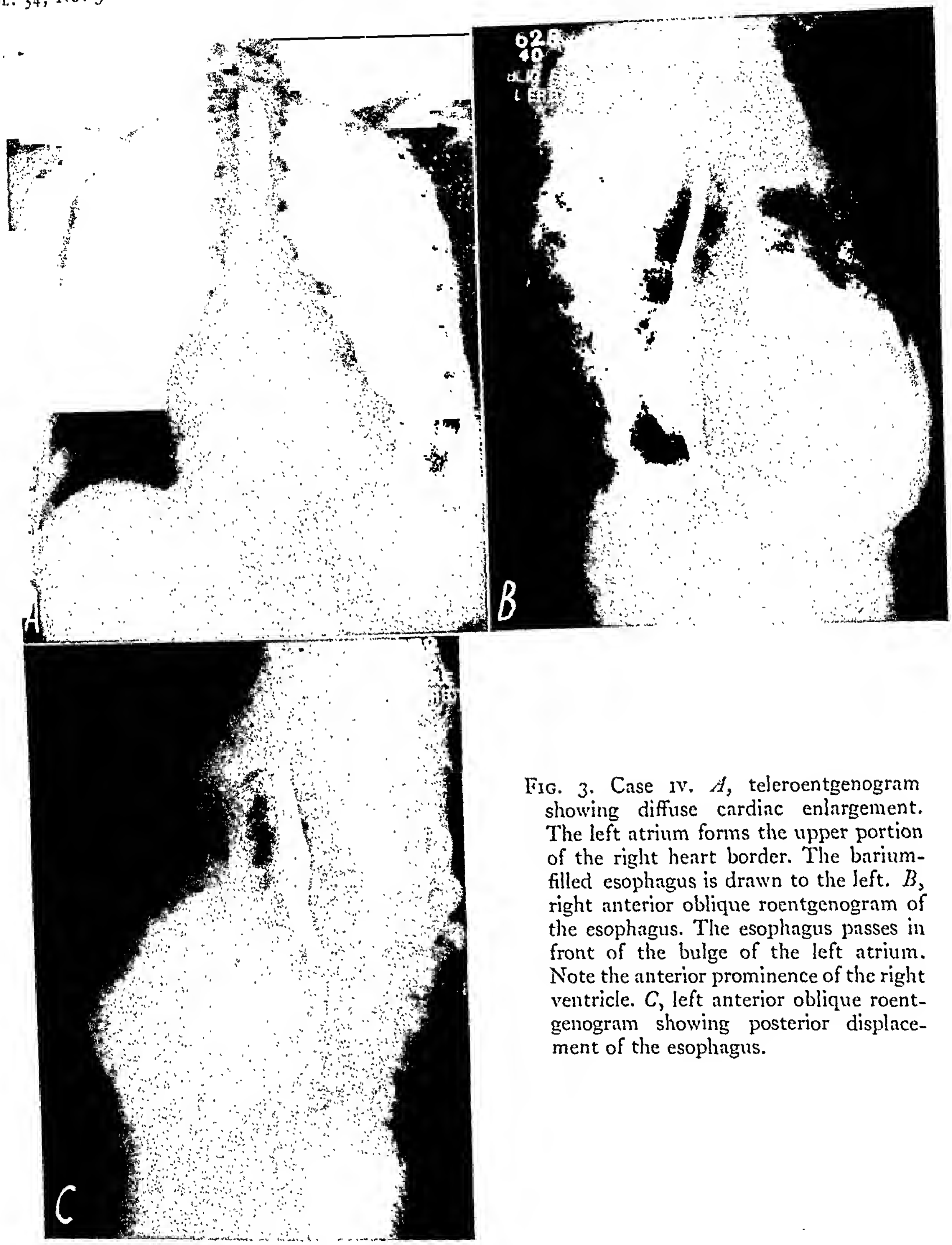

FIG. 3. Case IV. *A*, teleroentgenogram showing diffuse cardiac enlargement. The left atrium forms the upper portion of the right heart border. The barium-filled esophagus is drawn to the left. *B*, right anterior oblique roentgenogram of the esophagus. The esophagus passes in front of the bulge of the left atrium. Note the anterior prominence of the right ventricle. *C*, left anterior oblique roentgenogram showing posterior displacement of the esophagus.

systolic and diastolic murmurs were heard over the entire precordium. The liver was enlarged and tender. The blood pressure was 120/70. She was followed for the next two years in the out-patient department, always in mild congestive failure.

Roentgenoscopic and roentgenographic examination of the heart when she was ambulatory revealed marked cardiac enlargement, the heart shadow assuming the appearance associated with aortic and mitral valve disease. The aortic knob was inconspicuous. On the

overpenetrated teleroentgenogram the left atrium could be seen forming the upper third of the right heart border. In the right anterior oblique position the left atrium bulged far into the posterior mediastinum. The barium-filled esophagus was shifted to the left and posteriorly closely approximated the transverse thoracic and descending aorta, and in the right anterior oblique position it passed well in front of the bulge of the left atrium.

Comment. The atypical position of the esophagus with advanced left atrial dilatation indicates the possibility of aortic-esophageal adhesions.

CASE V. S. B., female, aged forty-six, first had congestive heart failure with dyspnea, palpitation and peripheral edema at the age of thirty. She had been unaware of heart disease until that time. Since then there had been several episodes of acute congestive heart failure which responded to prolonged bed rest and diuretics. Loud blowing systolic and diastolic murmurs were heard over the entire precordium, and auricular fibrillation was present. The blood pressure was 110/50.

Roentgenoscopic and roentgenographic examination of the chest showed the heart to be globular in shape and considerably enlarged. The aortic knob was inconspicuous. The left auricle was markedly enlarged, protruding into the posterior mediastinal space. The barium-filled esophagus was deviated to the left and posteriorly, following the transverse thoracic and descending thoracic aorta, which was moderately elongated and tortuous. Calcifications could be seen roentgenoscopically in the mitral valve leaflets.

Comment. This patient presents classical findings of double mitral and aortic valve disease with advanced left atrial dilatation. The esophagus is closely apposed to the aorta indicating aortic-esophageal adhesions which prevent the expected posterior and dextroposition of the esophagus. The tortuosity of the descending thoracic aorta is interesting because it indicates the superimposition of degenerative changes incident to middle life on the supposed rheumatic aortitis. The aortic-esophageal adhesions must have been established before the left atrial dilatation of the [illegible] of the aorta appeared.

CASE VI. M. C., male, aged fifty [illegible] known history of rheumatic fever. He [illegible] aware of his cardiac condition [illegible] thirty-five years. There had been [illegible] dyspnea, orthopnea and peripheral [illegible] which responded to bed rest and diuretics [illegible] many years. Auscultation revealed systolic [illegible] diastolic murmurs over the apex and base [illegible]dicative of double mitral and aortic valve disease. The blood pressure was [illegible].

Roentgenoscopic and roentgenographic examination of the chest revealed marked enlargement of the left ventricle to the left and downward, with straightening of the left cardiac border. The upper third of the right heart border was formed by the left atrium, which could be seen protruding far into the posterior mediastinal space in the right anterior oblique position. The barium-filled esophagus [illegible] well in front of the bulge of the left atrium. In the posteroanterior view the esophagus was deviated towards the left, following the descending thoracic aorta. Slight elongation and early dilatation of the aortic knob, with calcified plaques, was present. The aorta [illegible] 3.3 cm. in diameter. Calcifications in the mitral and aortic leaflets were identified roentgenoscopically.

Comment. The aortic-esophageal adhesions prevented the usual displacement of the esophagus noted with advanced left atrial dilatation. Degenerative arteriosclerotic changes were present in the aorta.

SUMMARY

The displacement of the esophagus [illegible] ly associated with left atrial dilatation [illegible] posteriorly and toward the right. In [illegible] tients reported here with advanced left atrial dilatation associated with the [illegible] mitral and aortic valve disease the [illegible] eal displacement was [illegible] and the left and posteriorly, closely following the [illegible] thoracic and descending [illegible] is suggested that the [illegible] position of the esophagus [illegible] esophageal adhesions [illegible]

[illegible]

REFERENCES

1. BOYD, WILLIAM. The Pathology of Internal Diseases. Second edition. Lea & Febiger, Philadelphia, 1935, p. 24.
2. CHIARI, H. Ueber Veränderungen in der Adventitia der Aorta und ihrer Hauptäste im Gefolge von Rheumatismus. *Beitr. z. path. Anat. u. z. allg. Path.*, 1928, *80*, 336–360.
3. EPSTEIN, B. S. Evaluation of teleroentgenographic mensuration and cardiac roentgenoscopy in diagnosis of early mitral valve disease. AM. J. ROENTGENOL. & RAD. THERAPY, March, 1945, *53*, 259–269.
4. GRAY, S. H., and AITKEN, L. Late gross lesions in aorta and pulmonary artery following rheumatic fever. *Arch. Path.*, 1929, *8*, 451–463.
5. GROSS, L. Lesions in roots of pulmonary artery and aorta in rheumatic fever. *Am. J. Path.*, 1935, *11*, 631–646.
6. GROSS, L., KUGEL, M. A., and EPSTEIN, E. Z. Lesions of coronary arteries and their branches in rheumatic fever. *Am. J. Path.*, 1935, *11*, 253–280.
7. KLOTZ, O. Rheumatic fever and the arteries. *Tr. Ass. Am. Phys.*, 1912, *27*, 181.
8. MACCALLUM, W. G. Rheumatic lesions of left auricle of heart. *Bull. Johns Hopkins Hosp.*, 1924, *35*, 329.
9. New York Heart Association, Criteria Committee. Nomenclature and Criteria for Diagnosis of Diseases of the Heart. Fourth edition. New York Tuberc. & Health Assoc., 1939, Chap. 4, p. 196.
10. PAPPENHEIMER, A. M., and VONGLAHN, W. C. Lesions of aorta associated with acute rheumatic fever and with chronic cardiac disease of rheumatic origin. *J. Med. Research*, 1924, *44*, 489.
11. PAPPENHEIMER, A. M., and VON GLAHN, W. C. Case of rheumatic aortitis with early lesions in the media. *Am. J. Path.*, 1926, *2*, 15–17.
12. PAPPENHEIMER, A. M., and VON GLAHN, W. C. Studies in pathology of rheumatic fever. *Am. J. Path.*, 1927, *3*, 583–594.
13. RIGLER, L. G. Visualized esophagus in diagnosis of diseases of heart and aorta. AM. J. ROENTGENOL. & RAD. THERAPY, 1929, *21*, 563–571.
14. SCHWEDEL, J. B. Use of barium-filled esophagus in x-ray study of abnormalities of heart and aorta. *Am. Heart J.*, 1937, *13*, 723–730.
15. Unpublished observations.

ANOMALOUS RIGHT SUBCLAVIAN ARTERY*

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AN ANOMALOUS right subclavian artery is seldom seen in the dissecting room. Anson[1] found 3 cases in 102 laboratory specimens, and Goldbloom[7] discovered 4 specimens among 225 bodies. The incidence in Dolgopol's series[6] was 0.7 per cent. Occasional cases, found at autopsy or in the dissecting room, have been reported by others.[2,5,10,12,13] That this anomaly is not rare may be judged from the fact that Holzapfel[9] found over 200 specimens up to 1899. It is unusual, therefore, that it has not been seen with comparative frequency during life. The roentgenologic diagnosis of this condition in the living patient has been reported twice by Dahm[4] and once each by Günsel[8] and Kommerell.[11] Two cases reported by Saupe were reviewed by Renander[14] who believes that they are correctly classified as cases of right aortic arch rather than as the anomaly under discussion. In view of its rarity in the literature, it is felt desirable to review the embryology and anatomy of this anomaly, and to record another case in which the diagnosis was made during life.

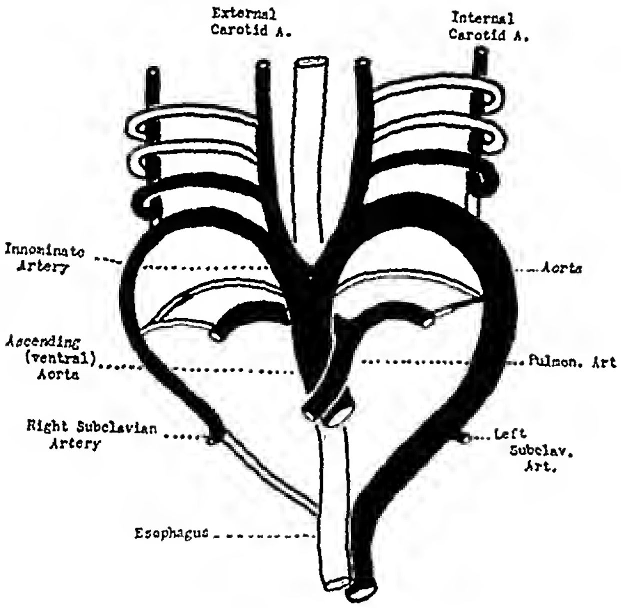


FIG. 1. Normal development (after Renander[14]). The vessels which persist are in solid black. The ventral root of the right fourth branch forms the innominate artery. The proximal part of the right subclavian artery is formed from the arch of the right fourth branch; the distal part of the subclavian artery is formed from the proximal part of the right dorsal aorta. The left fourth arch, its ventral root, and the left dorsal aorta form the aortic arch.

It will be recalled that in the embryo at five weeks there are six pairs of vessels connecting the ventral and dorsal paired aortae. Of these, the ventral root of the right fourth arch forms the innominate artery (Fig. 1). The arch of the right fourth branch makes up the proximal part of the subclavian artery; the distal part of the subclavian artery is formed from the right dorsal aorta. The left fourth arch and its ventral root form the aortic arch.

Abnormally, however, the right subclavian artery may develop from the distal portion of the right dorsal aortic root as an offshoot from the adult ascending aorta (Fig. 2). The remnant of the dorsal aortic root may persist as a diverticulum. The anomalous artery frequently springs from this diverticulum, as evidence of which Holzapfel found the site of origin to be dilated in 33 of 55 cases.

On occasion, the aortic arch may be formed from the right fourth branch and the left subclavian artery from the left fourth branch (Fig. 3*A*). This is, in effect, a "mirror image" of the normal development of the aorta and the right subclavian artery. Still another anomaly may result when the left subclavian arises from an anomalous right aortic arch. This form (Fig. 3*B*), probably the rarest,[3] is a "mirror image" of the normal aorta and an anomalous right subclavian artery.

* From the Roentgenology Service, Lovell General Hospital, Fort Devens, Massachusetts.

In most of the anatomic specimens Dahm has found that the anomalous artery arises from the arch, and only rarely from the descending aorta. Its site of origin is most often the posterior aspect, and only rarely the superior wall of the aorta. Since the anomalous artery arises on the left as the fourth, rather than as the first or part of the first main trunk, it must cross the spine to reach the right arm (Fig. 4). It usually runs between the esophagus and the spine, to which it may be adherent. This relationship to the posterior and left side of the esophagus is most important since it provides the only clue by means of which the diagnosis may be made in vivo. Occasionally, however, the anomalous vessel crosses anteriorly to the esophagus, and rarely, even anterior to the trachea. Since the site of origin of the subclavian artery is lower than the origin of the brachial artery, its course is therefore also upwards, as well as to the right, behind the esophagus. It may cross the spine anywhere from the level of the sixth cervical to the fourth thoracic vertebra.

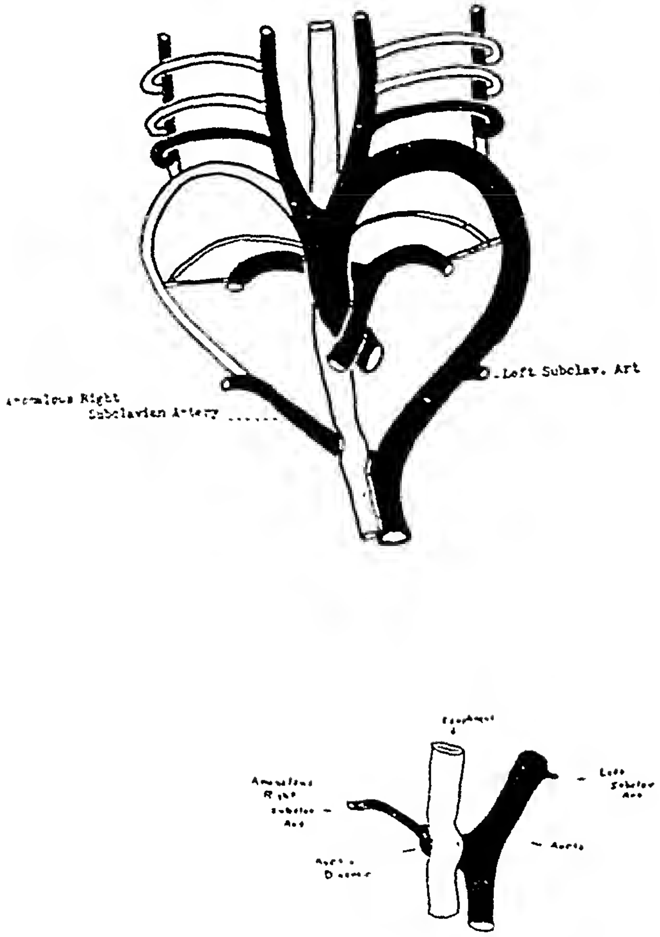


Fig. 2. Abnormal development (after Renander[14]). The right subclavian artery may develop from the distal portion of the right dorsal aortic root, as an offshoot of the adult aorta. The remnant of the dorsal aortic root may persist as a diverticulum which frequently gives origin to the anomalous vessel (see inset). Note the relationship of the esophagus to the anomalous vessel.

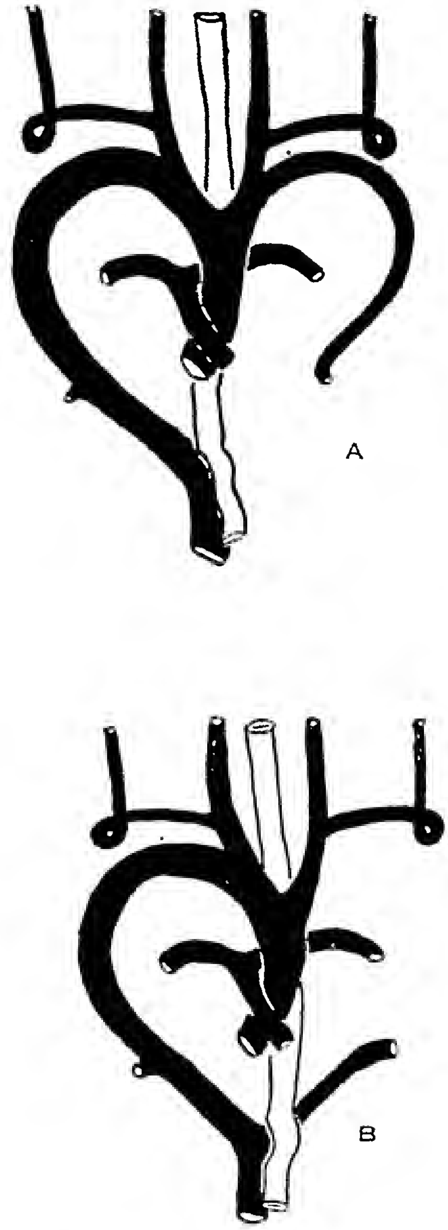
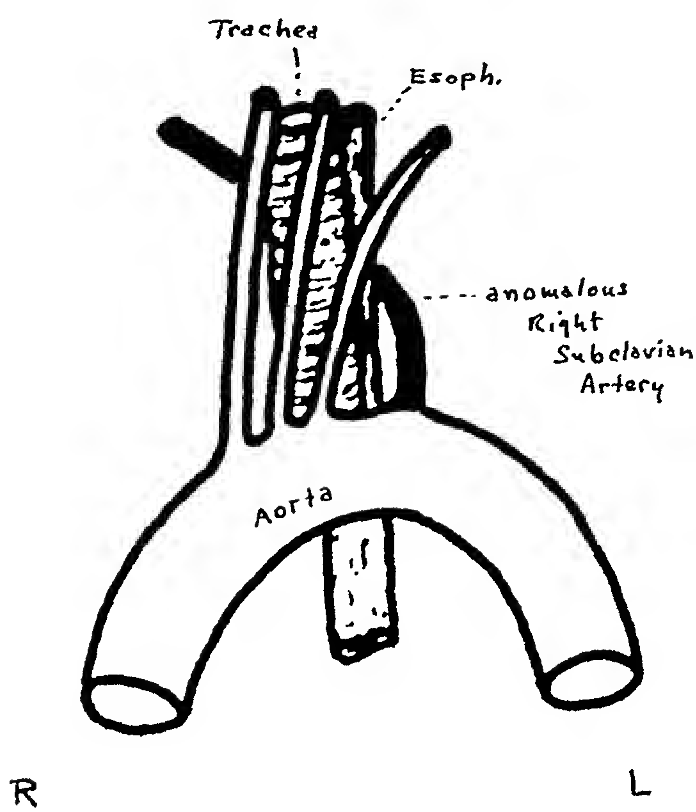


Fig. 3. Other abnormalities of development. *A*, occasionally, the aortic arch may be formed from the right fourth branch, and the left subclavian artery from the left fourth branch. This is a "mirror image" of the normal development of the aorta and the great vessels. *B*, the rarest anomaly is that which results when the left subclavian artery arises from an anomalous right aortic arch. This is a "mirror image" of the normal aorta and an anomalous right subclavian artery.

From a study of specimens Dahm states that the dilatation of the beginning of the artery (diverticulum of the aorta) may extend to the right side of the esophagus and even beyond. In one of his cases (Fig. 7, Case 2) the course of the esophagus was so altered that it resembled an "S" in reverse. One anatomic specimen indicated that it



View from in front

Fig. 4. Sketch of an anatomic specimen (semidiagrammatic). The anomalous right subclavian artery, in solid black, arises from the aorta as the last main branch; it courses towards the right behind the esophagus.

would cause an impression on the esophagus posteriorly and to the left instead of to the right.

Another important anomaly occurs in association with that of the artery. The recurrent laryngeal nerve on the right passes directly to the laryngeal structures instead of hooking about the subclavian artery. This, and the rare case in which the subclavian artery crosses anterior to the trachea, may be a source of anxiety to the surgeon during the course of a thyroidectomy.

Patients with right subclavian artery anomaly occasionally complain of dysphagia, although there is usually no esophageal obstruction (dysphagic lusoria). Because of pressure on the artery, there may be inequality of the radial pulses. It is possible that the symptoms produced may be similar to those of the scalenus syndrome. In a case reported by Kirby[10] the anomalous artery was perforated by a sharp bone piercing the esophagus.

CASE REPORT*

A white male, aged forty-six, was first seen by his doctor late one night complaining of severe burning and intermittent substernal pain of about two hours' duration. There was radiation of the pain down both arms. He had no difficulty in swallowing. His past history was inconsequential. He was very restless and apprehensive, and appeared to be suffering severely with each attack of the intermittent pain. The only positive findings were a blood pressure of 180/100, and slight epigastric tenderness. A quarter of a grain of morphine sulfate brought no relief. He felt better the next morning; his blood pressure was then 110/80. His chest was strapped and this seemed to relieve him. The blood count and Wassermann reaction were normal. The patient refused to submit to an electrocardiographic examination, but requested that he be referred for an examination of his stomach and duodenum.

The heart and lungs were normal roentgenoscopically. The aortic knob was in normal position and pulsated normally. On examination of the esophagus there was noted a groove-like defect on the posterior wall extending from just above the level of the aortic arch upwards and to the right. Roentgenograms made during the roentgenoscopic examination showed that the defect was due to external pressure and not to an intrinsic lesion (Fig. 5 and 6). The remainder of the examination was negative.

The diagnosis of this condition during life without roentgenologic means is hardly possible. The roentgenologic demonstration depends, as mentioned above, on the anatomic relationship of the anomalous vessel to the esophagus. In its course posterior to the esophagus the anomalous artery indents this structure, and so provides the sole di-

* Acknowledgment is made to Dr. H. B. Copleman for the case history.

agnostic clue. Only the very rare case in which the artery proceeds to the right in front of the esophagus or in front of the trachea will escape detection by roentgenologic means.

This defect, in the cases reported, is concave to the left. Specimens have been noted[4] in which the esophageal indentation would have been to the right. The defect is usually situated just at or above the level of the aortic arch. Here again, the variation in the specimens is such that a defect may be produced at the level higher or lower than that of the aortic arch.

The shape of the defect in the posterior aspect of the esophagus may be a segment of a circle with a diameter of about ½ to 1 inch. The larger pressure defects are probably due to the dilated portion (aortic diverticulum) from which the artery originates. This type of defect was present in the cases reported by Kommerell, Günsel and in Dahm's first case (Fig. 7). In Dahm's

Fig. 5. Posteroanterior view of chest with barium in esophagus (retouched). Groove-like defect (black arrows) in the barium-filled esophagus, which extends from the level of the aortic arch (white arrow) upwards and to the right.

Fig. 6. Right oblique projection (spot roentgenogram) of barium-filled esophagus. Pressure defect on the posterior of the esophagus.

second case, the esophagus took the course of an "S" in reverse. The lower defect, concave to the left, was larger than the upper, concave to the right, and was probably produced by the dilated diverticulum. The upper defect was probably produced by the anomalous artery itself. In the new case which is presented, the defect extended from the aortic arch obliquely upwards and to the right, and was probably produced by pressure of the anomalous artery directly on the esophagus.

In spite of the absence of operative or autopsy proof, the evidence in favor of this diagnosis seems incontrovertible after a comparison with the cases and anatomic specimens published in the literature.

The esophageal defect produced by a right aortic arch is almost the same as that described for the anomalous right subclavian artery. The aortic anomaly displaces the esophagus to the left and anteriorly (Fig. 8). The demonstration of a normally pulsating aortic arch, which is not in contact with the esophageal defect, at

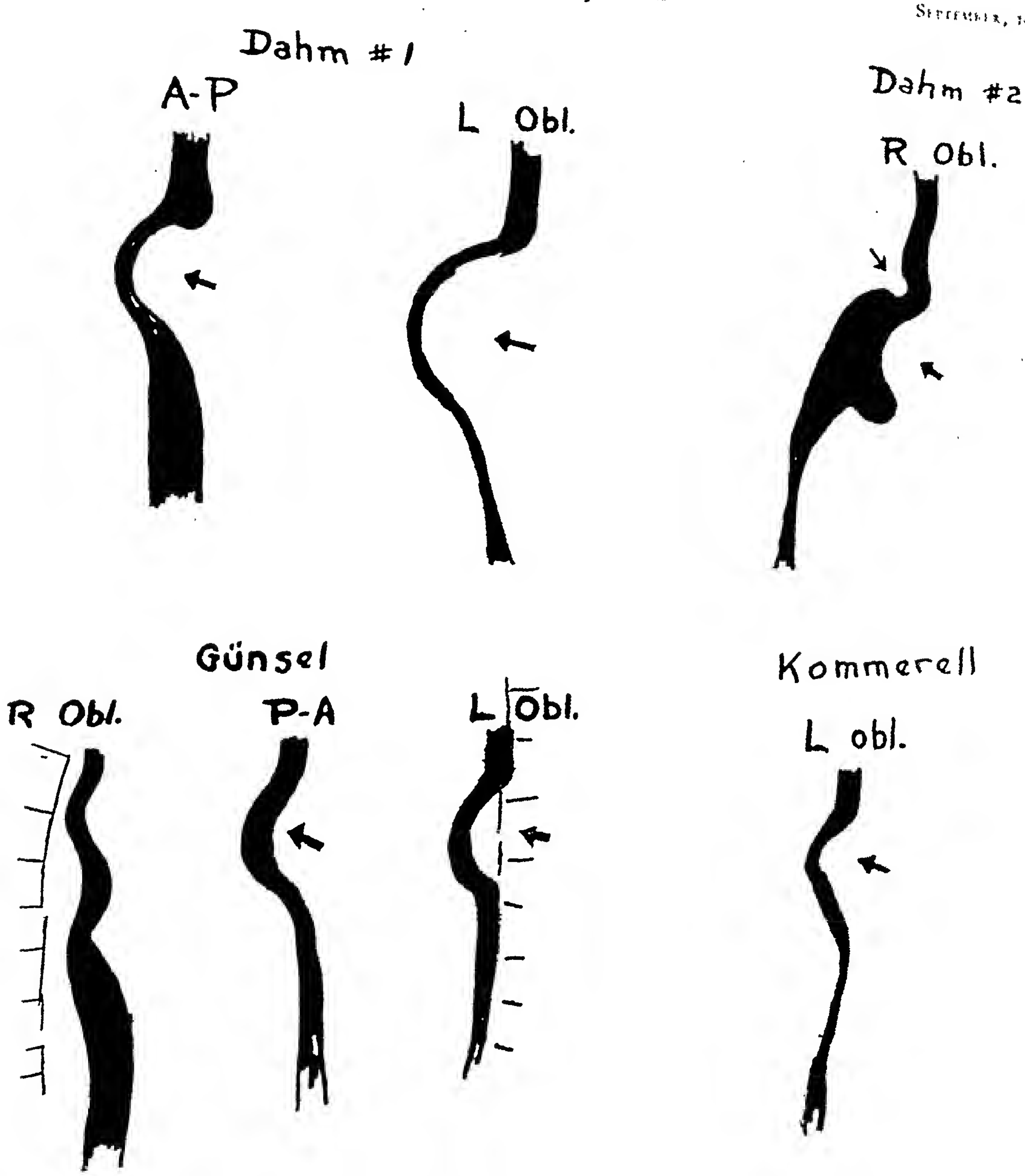


FIG. 7. Tracings of the course of the esophagus in each of the 4 cases reported in the literature, in which the diagnosis was made during life.

the left side of the vertebral column, must be made in order to arrive at the true diagnosis. This set of conditions was observed in the case reported above.

Lesions of the mediastinal lymph nodes must also be excluded in the differential diagnosis. It is conceivable that a destructive lesion of the vertebrae with formation of a soft tissue mass anteriorly may produce a similar, but non-pulsating, defect in the esophagus.

SUMMARY

The embryology and anatomy of anomalous right subclavian artery are described. The literature is reviewed and the roentgenologic diagnosis discussed. A case showing the characteristic roentgenologic sign described in the literature is presented.

Fig. 8. Right aortic arch. *A*, right oblique view; *B*, posteroanterior view; *C*, left oblique view. The defect in the barium-filled esophagus, as seen in the oblique projections, is due to pressure from behind, and is similar to the defect produced by an anomalous right subclavian artery. Note, however, that in the posteroanterior projection the esophagus is characteristically on the left side of the anomalous aortic arch.

REFERENCES

1. Anson, B. J. Anomalous right subclavian artery. *Surg., Gynec. & Obst.*, 1936, *62*, 708–711.
2. Belou, P., and Bottini, A. Presentación de una deposición anómala de arteria subclavia con porción inicial retro-esofágica, etc. *Rev. Asoc. méd. argent.*, 1937, *51*, 113–114.
3. Biedermann, F. Der rechtsseitige Aortenbogen im Röntgenbild. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1931, *43*, 168–187.
4. Dahm, M. Zur Eindellung der Speiseröhre bei links entspringender Arteria subclavia dextra. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1940, *62*, 108–114.
5. DeGaris, C. F. Aortic axillary collaterals and pattern of arm arteries in anomalous right subclavian artery. *Am. J. Anat.*, 1932, *51*, 189–213.
6. Dolgopol, V. B. Note on incidence and symptomatology of retro-oesophageal right subclavian artery. *J. Tech. Methods*, 1937, *17*, 106–107.
7. Goldbloom, A. A. Anomalous right subclavian artery and its possible clinical significance. *Surg., Gynec. & Obst.*, 1922, *34*, 378–384.
8. Günsel, E. Dysphagia lusoria bei Arcus aortae dexter und sinister. *Röntgenpraxis*, 1940, *12*, 346–348.
9. Holzapfel, G. Ungewöhnlicher Ursprung und Verlauf der Arteria subclavia dextra. *Anat. Hefte*, 1899, *12*, 373–531.
10. Kirby. Quoted by Dolgopol.[6]
11. Kommerell, B. Verlagerung des Ösophagus durch eine abnorm verlaufende Arteria subclavia dextra (Arteria lusoria). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1936, *54*, 590–595.
12. Pontes, A. A arteria subclavia direita ultima collateral do arco aortico, retroesophageana. *Brasil-med.*, 1936, *50*, 1079–1080.
13. Pontes, A. Nosso 10° caso de arteria subclavia direita retro-esophageana, ultima collateral do arco aortico. *Brasil-med.*, 1938, *52*, 780–781.
14. Renander, A. Roentgen-diagnosed anomaly of the oesophagus and arcus aortae. Dysphagia lusoria. *Acta radiol.*, 1926, *7*, 298–308.

ROENTGENOLOGICAL DIAGNOSIS OF BENIGN TUMORS (SINGLE POLYPS) OF THE COLON

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BENIGN tumors of the colon are comparatively rare. Lawrence found that polyps occurred in 2.3 per cent of 7,000 autopsies. Compared with this frequency the roentgenological literature shows an astonishing scarcity of reports of such cases. While reporting such a case we would like to discuss the reason why these lesions are so infrequently reported in the roentgenological literature.

A search of the recent literature and of such textbooks as those by Golden, Schinz, Assmann, Stierlin and Chaoul, Chaoul and Adams, H. H. Berg, Maingot-Sarasin-Duclos, Feldman, Bargen and the recently published work by Bockus fails to reveal roentgenograms of solitary, benign adenomas of the colon. Rankin, Bargen and Buie show a case of a polypoid mass in the cecum, which turned out to be a fibroma. The only book, as far as we know, which contains a roentgenogram of this condition is that by Buckstein. This book contains 2 cases of polyps of the colon.

Polyps of the colon are reported in the publications of Weber, Gilbert and Kadrnka, Schatzki, Root, Jenkinson and Waskow and also Kennedy, Dixon and Weber.

These are the important signs which should make one search for the presence of intestinal polyps: (1) bleeding from the rectum; (2) intestinal obstruction.

Bleeding from the intestinal tract is always an alarming symptom. Most of the polyps are very vascular and therefore easily damaged by hard fecal matter. Bleeding is frequently the first symptom. The second symptom is that of partial intestinal occlusion. Polyps, like malignant tumors, often form the head of an invaginated portion of the bowel. Such cases are reported by Schatzki and others. The clinical symptoms are the same in malignant and benign tumors. The signs of partial obstruction or invagination are in the foreground; its mechanical results overshadow every other symptom. The indication for surgical intervention is obvious. Benign tumors are rarely so large as to effect complete occlusion of the lumen of the bowel. There have been no reports with respect to such complete occlusion as far as we know.

What other symptoms would lead us to suspect a polyp of the large intestine? These tumors give no characteristic sign which could not also be found in a malignant tumor. However, there is one symptom, in our experience, which might cause us to look for a pedunculated tumor. We found in our first case, as in a similar case of a pedunculated carcinoma, the following complaints: The patient experienced no pain except after the intake of laxatives or cleansing enemas. This symptom is probably due to the fact that the peristaltic waves of the colon try to transport the polyp caudally and, in doing so, are exerting a pull on the colonic wall at the site of the attachment of the tumor. These pains are cramplike and can easily be confused with any localized spasm of the colon, which may be caused by many different conditions. In our case the pains were localized in the right hypochondrium. The patient, in fact, came for treatment of an "inflammation of the gallbladder." However, after ruling out any pathological condition of the gallbladder a roentgenological study of the colon was undertaken. The localization of the pains could easily have been caused by disease of the gallbladder, as the patient was slender and there was the possibility of a low position of the gallbladder.

The best method to find a polypoid growth of the colon (unless it can be reached by the proctoscope) is by enema. Barium given by mouth is very frequently mixed

with fecal matter when it reaches the colon. Therefore, unless a very large tumor or a tumor heading an invagination is present, it is practically impossible to differentiate between a pathological mass and fecal matter.

The complete filling of a colon by the usual barium enema usually outlines the entire viscus to such an extent that the tumor is not visible. Jenkinson and Waskow use a compression device and visualize the tumor by this means. This entails very careful roentgenoscopy as some of the polyps are very small. Another method is that of air insufflation into the colon after evacuation of the contrast enema. There is no question that this method has its definite value as Buckstein, Root, and Brust have demonstrated. "The tumor," says Root, "is quite prominent after the air injection, however, since it is coated with barium and is seen against the dark background produced by the air."

In previous publications with Jacobi, I have recommended the study of the mucous membrane by special attention to the mucosal pattern in searching for pathological conditions of the colon. In these papers we have fully discussed our method which is based upon the fundamental studies of Forssell and Berg. Essentially the mucosa of the colon after evacuation of a barium enema has a very definite appearance. There is a regular pattern of folds, especially in the transverse colon; a pattern which is based on a sequence of longitudinal and transverse folds. The folds have a certain amount of variation. However, they never have any similarity to a tumor mass. Any abnormality of the mucosal pattern should arouse the attention of the examiner. In cases of polyps, the regularity of the mucosal pattern is suddenly interrupted. The tumor appears like a cherry or a plum in the axis of the colon. As these tumors have a lobulated surface, the barium is retained in its folds and therefore outlines the contour of the polyp. For the further study of these tumors a compression device must be used. It would be rather wasteful to use 14 by 17 inch films, as long as the lesion is small. We take four exposures on an 8 by 10 inch film under varying angles and compression with translucent cassettes, while the object is visible on a fluoroscopic screen (Fig. 3). This fluororoentgenography is a procedure which saves much material.

The fluororoentgenographic device enables us to exert localized compression, a very important factor in the differential diagnosis. The only round shadow which might be confused with a polypoid mass is fecal matter. The localized compression may occasionally crush or dislocate the barium-covered fecal matter during roentgenoscopy, whereas a polyp, of course, does not disintegrate under our eyes.

CASE REPORTS

Case I. Mrs. G., aged fifty, had been constipated for fifteen years. Appendectomy had been performed eighteen years before. For the last four years she had had pains in the middle of the right side of the abdomen. These pains had increased during the last two months and were supposed to be caused by an inflamed gallbladder. The patient attributed her pains to "gas." After taking cathartics the pains would radiate across the abdomen and would frequently be accompanied by a burning sensation. Occasionally, the pains radiated to the back, but subsided after the ingestion of food. The appetite was fair. The stools had never contained blood, but did contain mucus. Six months ago a sister of the patient had undergone an operation for cancer of the sigmoid.

The physical examination of the patient did not reveal any abnormalities with the exception of a tenderness 2 inches below the region of the gallbladder. No masses could be felt. The liver was not enlarged and was definitely not connected with the local tenderness.

The findings on roentgen examination were as follows: Stomach and duodenum were normal. Barium enema: The barium filled the entire colon without delay. The colon was of normal size, shape, and position (Fig. 1). No defects were visible. After evacuation a round polyp became visible in the right side of the transverse colon (Fig. 2 and 3). The gallbladder was well visualized after an oral Graham test and was normal in appearance. A diagnosis was

Fig. 1. Case 1. Single benign polyp of the transverse colon. Roentgenogram taken following barium enema.

Fig. 2. Case 1. Post-evacuation roentgenogram showing single benign polyp of the colon.

Fig. 3. Case 1. Special views of a benign polyp of the transverse colon.

made of a polyp in the right side of the transverse colon.

At operation (Dr. Ralph Colp) a pedunculated polyp was found in the transverse colon. The tumor was resected. The pathologist's report revealed that the tumor mass was almost round and strawberry like in appearance, measuring 1.5 cm. in diameter. It was soft and friable, and dark red in color. The pedicle was short and measured only a few millimeters in length (this short pedicle may have been caused by formalin fixation). Microscopically, the tumor represented a typical adenomatous structure (Fig. 4). The long, delicate papillae radiated from the center which was actually a part of the pedicle; the latter was made up of a fibrous connective tissue. The papillae were, for the most part, composed of single layers of regular cylindrical cells (Fig. 5). There were, however, areas of papillae composed of multiple layers of cylindrical cells with hyperchromatic nuclei and a moderate degree of cell atypism. Occasional mitoses, which were found in these areas, were not atypical. Their basement membranes were intact throughout. Pathological diagnosis: Pedunculated adenomatous polyp with moderate cell atypism.

Fig. 4. Case I. Photomicrograph of the single benign polyp of the transverse colon.

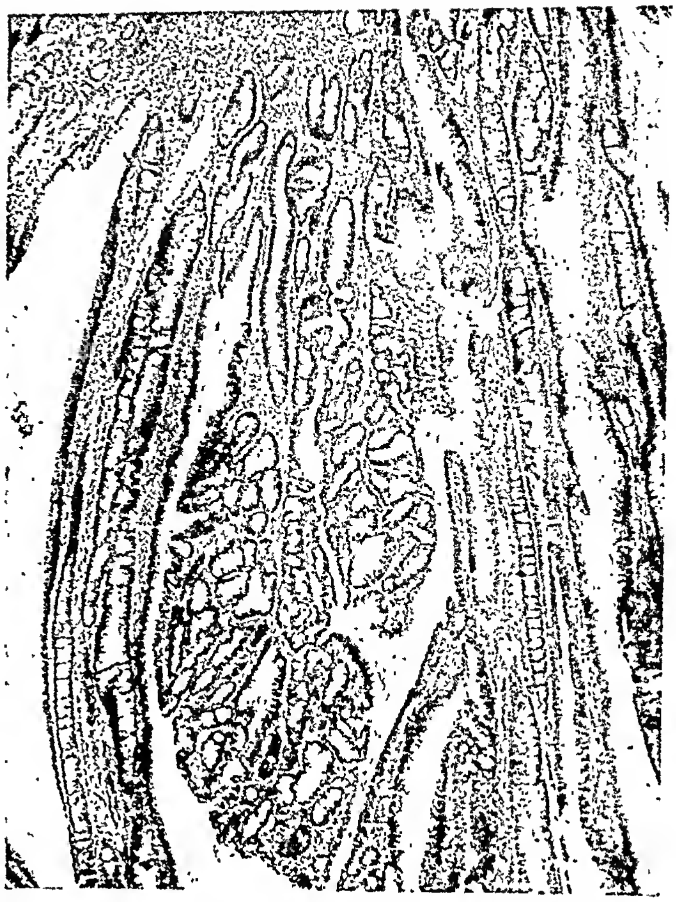

Fig. 5. Case I. High power photomicrograph of the benign polyp.

Case II. This patient was a middle aged woman with indefinite abdominal complaints. There was no bleeding, no loss of weight. A barium enema revealed an irritable colon; no defects could be visualized. A study of the mucosa revealed a small polyp in the region of the rectosigmoid (Fig. 6). No further polyps could be seen in the remainder of the colon. Proctoscopy confirmed the diagnosis and the tumor was removed surgically.

The greatest difficulty in the differential diagnosis of these single polyps is the presence of fecaliths. We cannot impress too much on our patients that they should be well prepared for a colon examination. Only too often we are confronted with patients who did not follow our instructions. They either did not take a cleansing enema at home, or they took it improperly. Large carcinomas will show up especially when they are obstructive; however, smaller lesions, like polyps, or mucosal changes in the different types of colitis, are impossible to evaluate correctly. This problem con-

FIG. 6. Case II. Single benign polyp of the rectosigmoid.

FIG. 7. Case III. No polyp but fecal matter. [illegible]

fronted us at just about the time when we were dealing with the above reported case.

CASE III. A middle aged woman complained of pains in the left lower quadrant. The history was somewhat indefinite. There was no bleeding, some loss of weight, constipation and bloated feeling. The roentgen examination (barium enema) showed no pathological condition on the roentgenogram taken after filling of the colon. However, after evacuation (Fig. 7) a round mass was found in the descend-

FIG. 8. Case III. No polyp but fecal matter. Roentgenogram taken after air insufflation.

ing part of the colon, a mass which resembled the one seen in the previous case. Under roentgenoscopy, the mass could not be moved. Air was insufflated and another roentgenogram showed the round mass clearly defined against the background (Fig. 8), just as Rendich [illegible] it in polyps. After several days [illegible] tion of the colon failed to reveal any [illegible] tances of the descending [illegible] outlined and normal in appearance.

This case shows the importance of careful preparation of the patient [illegible] of reexamination. The [illegible] only able to demonstrate the [illegible] cannot reveal the nature of the [illegible]

SUMMARY

The roentgenological diagnosis of single benign polyps in the colon is discussed. Cases of this type are comparatively rare in the literature, which is strange since they are not too rarely found at autopsy. Apparently they are so often missed because the roentgenological studies of the colon are not always performed under careful preliminary preparation of the patient. Most of these benign tumors are too small to obstruct the lumen of the bowel and are generally overshadowed by the complete filling of the colon with the barium. The study of the mucous membrane of the colon after evacuation is stressed. Air insufflation is advisable, but interpretation must be made cautiously, as is demonstrated by our case in which fecal material was adherent to the wall of the sigmoid, thus simulating a polypoid tumor. In such cases, only re-examination after careful preparation will enable one to avoid making an incorrect diagnosis.

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REFERENCES

1. Brust, J. C. M. Solitary adenomas of rectum and lower portion of sigmoid. *Proc. Staff Meet., Mayo Clin.*, 1934, *9*, 625–631.
2. Buckstein, Jacob. Clinical Roentgenology of the Alimentary Tract. W. B. Saunders Co., Philadelphia, 1940, pp. 452 and 458.
3. Gilbert, R., and Kadrnka. S. Résultats cliniques de l'exploration radiologique du relief interne du gros intestin. *J. de radiol. et d'électrol.*, 1933, *17*, 401–427.
4. Jenkinson, E. L., and Waskow, W. L. Polyps of large bowel. *Radiology*, 1940, *34*, 489–495.
5. Kennedy, R. L. J., Dixon, G. F., and Weber, H. M. Polypoid lesions of colon of children. *Surg., Gynec. & Obst.*, 1943, *77*, 639–644.
6. Lawrence, J. C. Gastrointestinal polyps. *Am. J. Surg.*, 1936, *31*, 499–505.
7. Lust, F. J., and Jacobi, H. G. Roentgenographic studies of mucous membrane of colon; normal pattern. *Am. J. Digest. Dis. & Nutrition*, 1936, *3*, 108–111.
8. Lust, F. J. Fluororoentgenograph. Am. J. Roentgenol. & Rad. Therapy, 1940, *43*, 141–142.
9. Root, J. C. Roentgen examination of the colon. *Surg. Clin. North America*, 1939, *19*, 1071–1088.
10. Schatzki, R. Roentgenologic appearance of intussuscepted tumors of colon, with and without barium examination. Am. J. Roentgenol. & Rad. Therapy, 1939, *41*, 549–563.
11. Swinton, N. W., and Warren, S. Polyps of colon and rectum and their relation to malignancy. *J. Am. M. Ass.*, 1939, *113*, 1927–1933.
12. Weber, H. M. Roentgenologic demonstration of polypoid lesions and polyposis of large intestine. Am. J. Roentgenol. & Rad. Therapy, 1931, *25*, 577–589.

ROENTGEN IRRADIATION IN THE TREATMENT OF MARIE-STRÜMPELL DISEASE (ANKYLOSING SPONDYLARTHRITIS)*

AN ANALYSIS OF 160 CASES

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THE encouraging reports of Smyth, Freyberg and Lampe,[17] published in 1941 on the roentgen treatment of rheumatoid arthritis of the spine, offered definite hope for some relief in this resistant, chronic, and disabling condition. Roentgen irradiation, as they emphasized, has a place in the treatment of this disease.

The purpose of this report is to present an analysis of 160 cases of Marie-Strümpell disease which were treated by deep roentgen therapy in addition to the important orthopedic measures now employed by the Orthopedic Division of the Department of Surgery at Duke University Hospital. The therapy herein described was inspired by the publication of Smyth, Freyberg and Lampe, and is only a part of the measures now employed at Duke University Hospital in the treatment of this disease.

Kahlmeter,[10] 1930, published one of the earliest convincing reports of the effects of irradiation on arthritis. Scott,[16] in 1935, summarized 400 cases treated with roentgen irradiation and mentioned general body irradiation as a method of therapy. In addition to these workers, Sokolow, 1897; Moses, 1905; Dominici and Gy, 1907; Fried, 1934; Hellebrand, 1934; Toschke, 1941, and Balnoch, 1941, all reported use of the roentgen ray in the treatment of joint disease.

Marie-Strümpell disease is a chronic systemic disease of unknown etiology characterized by inflammatory changes in the synovial membrane and periarticular structures of the sacroiliac and spinal joints, with remissions and exacerbations of systemic and local manifestations. There is not complete agreement that this is a true atrophic arthritis although the pathological picture is indistinguishable from it. Clinically, the disease appears to be a separate entity. The course is that of a progressive deforming arthritis unless correction and prevention of the deformities can be instituted in time. Proper combined roentgen and orthopedic therapy offers a logical approach to this ideal of treatment.

Predisposing causes have been mentioned[4] including shock, fatigue, trauma, infection, exposure, heredity, and climate. However, the part these play in the disease has not yet been established.

Systemic manifestations vary greatly, depending on the duration of the disease and other factors. Loss of weight, progressive emaciation, muscle atrophy, accelerated pulse, and secondary anemia may all be evident during the course of the disease. Blood sedimentation rate is always elevated and is a guide in follow-up. Blood urea, non-protein nitrogen, carbon-dioxide combining power, total fat, cholesterol, calcium, phosphorus, alkaline and acid phosphatase determinations are normal. The basal metabolism and respiratory quotient are usually normal or only slightly altered.

Local manifestations are evident in the joints first involved. Migratory low back

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pains, stiffness, limitation of motion and muscle spasm are considered early symptoms and may be present for years. Later, contractures, deformities, fibrous and bony ankylosis with atrophy of the neighboring muscles reveal an advanced stage of the disease. The local manifestations, like the systemic manifestations, tend to occur in episodes of remissions and exacerbations. The essential relentless progress of the untreated patient presents an extreme change, not only in the joints of the spine and sacroiliac joints, but also in the surrounding ligaments and periarticular structures. Not infrequently in advanced stages the hip joints, shoulders, and even the temporomandibular joints may become involved.

Many variations of ankylosing spondylarthritis have been described. Marie-Strümpell disease characteristically begins in the sacroiliac joints and extends upward. "Spondylitis ankylopoietica," "spondylitis ossificans ligamentosa," "rheumatoid arthritis of the spine," and "spondylitis deformans" have been described in the literature separately but may be considered from the roentgen therapy viewpoint as various stages of the same pathological process.

Steinberg[18] presented a most detailed description of the pathological changes in atrophic arthritis in which he demonstrated the active inflammation of the synovial membrane, capsule, and surrounding soft tissue structures. The earliest change he found was marked proliferation of cells of the synovial membrane producing a layer of very vascular granulation tissue or pannus over the articular cartilage. With this alteration a similar active inflammatory process occurs, simultaneously, involving the connective tissue elements of the bone marrow below the articular cartilage. This latter reaction extends through the zone of temporary provisional calcification and destroys the articular cartilage nearest the bone, while the pathological process evidenced by proliferated synovial membrane destroys the articular cartilaginous surface. The result is that the articular cartilage is gradually destroyed by the two granulations. These two layers of active granulation tissue have marked potentialities of forming fibrous and bony ankylosis.

The clinical diagnosis of Marie-Strümpell disease is usually not difficult in well established cases. The patient flexes his body at the hips. The lumbar curve is flattened and the dorsal curve is exaggerated. The chest is flat and rigid, its expansion being limited. Spasm of the back muscles is variable. Many patients complain of pain and stiffness in the hips or shoulders in additicn to the spinal symptoms.

Prodromal symptoms include lassitude, anorexia, nervousness, accelerated pulse, low grade hyperpyrexia and loss of weight. The onset is gradual, as a rule, but tends to be more acute in the younger age groups. Most cases occur between the ages of twenty and forty-five. Seventy-seven per cent of this series were between twenty and thirty-nine years of age (Table II). The body type may be asthenic or sthenic, but with the progress of the disease the patient appears more of the asthenic type. Secondary anemia is frequently present and persists for a long time. The average hemoglobin in our series of cases was 70 per cent.

Pain is usually the presenting complaint. It is commonly described as an "ache," predominantly in the lower back and indefinitely localized in the early stages. Occasionally the pain is lancinating, radiating down the sciatic nerve, and may be brought on by movement. Typically, the pain varies, being worse in the morning, and may even awaken the patient early in the morning. The pain usually subsides during the day after protective muscle spasm limits the excursions of movements but it is definitely accentuated by fatigue and overexertion.

Stiffness is associated with the pain and becomes progressively worse and relentless except for occasional remissions. The stiffness, like the pain, is worse in the early morning, decreasing temporarily with motion and activity during the day, and becoming accentuated by fatigue.

Paravertebral muscle spasm is closely associated with the pain and stiffness, varying from day to day and usually being accentuated by motion.

Decreased capacity for exertion is almost a constant finding and is dependent on the degree of pain, stiffness, and paravertebral muscle spasm. The limitation of motion of the spine varies from slight diminution of flexion, extension, lateral and circular movements to complete fixation or "poker spine." Eighty-five per cent of our cases showed a decrease in chest expansion. This may become so pronounced that the vital capacity of the lungs is greatly lowered.

Increased sedimentation rate is usually present and with an altered Weltmann coagulation band may be an indication of the stage of activity of the disease. The two combined are considered the best possible clinical laboratory evidence of the presence of an actively growing pannus.

Leukocytosis may be present. About 50 per cent of our cases showed elevated peripheral white blood cell counts. Some reported cases have shown elevated albumin-globulin ratio and positive agglutinations for hemolytic streptococcus. The urine shows no characteristic changes.

ROENTGEN DIAGNOSIS

During the earliest inflammatory stage of the disease roentgenograms may be negative. However, oblique 45 degree angle roentgenograms may show changes about the articular facets of vertebrae. The facets of the twelfth dorsal vertebra are frequently affected earlier than others.

Usually the earliest detected changes are in the sacroiliac joints, and consist of decalcification and irregular trabeculation in the subchondral bone immediately adjacent to the joint space, with haziness and apparent widening of the joint space. The slight fragmentation of trabeculations as the marrow pannus develops gives pyknotic areas at the joint margins seen first along the lower half of the joint. The changes may be seen in one or both sacroiliac joints and may also be found in the vertebral articular facets.

Later changes are osteosclerosis of the subchondral bony margins, with destruction of the articular cartilage, narrowing of the joint space and trabeculation across the joint space. Calcification of the ligaments producing bridging of the intervertebral discs with ankylosis of the spine occurs in the final stage of the disease. Forestier[7] coined a distinguishing term "syndesmophyte" to apply to the bridging of vertebrae in Marie-Strümpell disease as contrasted to the "osteophyte" of degenerative arthrosis. Early roentgen changes are easily missed even by the competent roentgenologist and will not be discovered unless he gives careful attention to the sacroiliac joints.

DIFFERENTIAL DIAGNOSIS

Because of the value of early correct diagnosis and institution of proper therapy, Marie-Strümpell spondylarthritis should be differentiated from other conditions which may not offer so favorable a prognosis. The hypertrophic or degenerative type of arthrosis of the spine should be ruled out. Gonorrheal arthritis, luetic arthritis and tuberculous arthritis are sometimes difficult to distinguish. Subacute rheumatic fever, traumatic injuries and ruptured intervertebral disc must be excluded. Lumbosacral and sacroiliac "strain," "lumbago" and "neuritis" are convenient terms often applied incorrectly to the condition in its early stage by physicians not aware of the early diagnostic features of Marie-Strümpell spondylarthritis. The condition should not be confused with the adult type of atrophic arthritis, childhood type (Still's disease) or psoriasis arthropathica.

Careful history and physical examinations with adequate roentgenograms and repeated laboratory studies usually give an accurate diagnosis if the examiner has the condition in mind.

One hundred and seventy-two cases of

Marie-Strümpell spondylarthritis have been treated. One hundred and sixty of these 172 cases had sufficient data on their hospital charts to be of value in this analysis.

Sex. One hundred and thirty-seven cases, or 86 per cent, were male; 23 cases, or 14 per cent, were female.

Race. One hundred and fifty-one cases, or 94 per cent, were white; 9 cases, or 6 per cent, were colored. There were 130 white male patients and 7 colored male patients; 21 white female patients were treated and only 2 colored females (Table I).

Table I

TREATED CASES OF MARIE-STRÜMPELL SPONDYLARTHRITIS

Total No. in files: 172
160 of these 172 cases had sufficient data on hospital records to be of value

Total 160 Cases Analyzed

Sex		Race			
Male: 137	86%	White: 151	94%	Male	130
Female: 23	14%			Female	21
		Colored: 9	6%	Male	7
				Female	2

Table II classifies the patients according to age groups. One hundred and twenty-three cases, or 77 per cent, were between the ages of twenty and thirty-nine years.

Table II

AGE GROUPS TREATED

Age, yr.	Cases	
10–19	8	
20–29	65	123 cases or 77% between 20-39 years of age
30–39	58	
40–49	20	
50–59	6	
60–69	3	
Total	160	

Table III shows the duration of symptoms before treatment was begun. Almost 75 per cent of our patients had unrelieved symptoms for more than a year, emphasizing the persistent and insidious development of the disease if not treated. The value of early diagnosis is obvious when Table III is compared with Tables IX and X. The earlier correct diagnosis can be made and proper orthopedic and roentgen treatment instituted, the better the prognosis.

Table III

DURATION OF COMPLAINT BEFORE TREATMENT

3–12 mo.	41	26%	
1– 2 yr.	27	17%	Almost three-fourths of patients had symptoms for over one year.
2– 3 yr.	26	16%	
3– 4 yr.	14	8%	
4– 5 yr.	15	9%	
Over 5 yr.	41	24%	

Table IV classifies the stages of the disease into early disease (60 cases, or 40 per cent), moderately advanced disease (58 cases, or 37 per cent), and far advanced disease (38 cases, or 23 per cent). This classification is according to that of Smyth, Freyberg and Lampe[17] and is based on the roentgen findings.

Table IV

CLASSIFICATION BY ROENTGEN FINDINGS

Stage 1 — 60 cases — 40%
(Early disease) changes limited to sacroiliac joints

Stage 2 — 58 cases — 37%
(Moderately advanced disease) partially or completely obliterated sacroiliac joints, osteitis of the articular facets, and slight calcification of the spinal ligaments

Stage 3 — 38 cases — 23%
(Far advanced disease) sacroiliac joint ankylosed, and those in whom extensive paravertebral ligamentous calcification occurred, with or without involvement of girdle joints

Total 156. 3 cases with symptoms of 6 mo. or less upon review of films were negative roentgenographically.
1 case films reported positive elsewhere and not roentgenographed again.

Orthopedic treatment is outlined in Table V, and is patterned after the combined work of Swaim[19] and Baker[1,2] whose original papers should be referred to for more detailed analysis. The orthopedic treatment is most important, and satisfactory results cannot be expected if roentgen therapy is used alone. We believe that roentgen therapy finds its greatest useful-

TABLE V

ORTHOPEDIC TREATMENT

Swaim,[13] Baker.[14] Muscle spasm exists for years before actual ossification of ligaments takes place

1. Begin as early as possible
    a. gradual hyperextension
    b. relaxation of muscles
    c. corrective exercise to straighten spine and increase chest expansion
    d. immobilization of spine to hold correction
2. Systemic support
    a. high vitamin, low carbohydrate diet
    b. bed rest, hard mattress, etc.
    c. physiotherapy, heat massage, etc.
    d. combat anemia
    e. psychological encouragement
3. Educational

ness in being the important agent which allows orthopedic treatment and correction of the deformities to be tolerated by the patient.

The following factors have been used in the roentgen treatment: 200 kv., 30 to 50 cm. distance, 0.5 mm. Cu plus 1 mm. Al added filtration, 8 to 25 ma., giving a half-value layer of 1.1 mm. copper. The spinal column is blocked off into three or four elongated fields by lead shields. Fields vary from 160 to 260 sq. cm., but need not be wider than 8 to 10 cm. to be certain that the lateral spinal ligaments are included in the beam. We use a roughly triangular field for the lumbosacral and sacroiliac joints, including them in one field.

Two or three fields are treated every day or every other day, giving a dose (without backscatter) of 150 r, measured in air, to each field for three or four treatments or a total dose of 450 r or 600 r (in air) per field per series. The skin dose is approximately 215 r per field per treatment and the depth dose at the anterior interspinous ligaments is calculated in the neighborhood of 65 to 85 r per field per treatment for the average patient. One series gives an average depth dose of about 220 to 250 r and a skin dose of 645 to 860 r.

Young women are treated with caution and less total dosage per series. We have used intermediate voltage, [illegible] cm. distance, 0.25 mm. Cu filter for the sacroiliac field in order to decrease the depth dose at the ovaries. Fortunately, the disease is not common in young women.

The series of deep roentgen treatments is repeated at the end of six to eight weeks if clinical re-evaluation suggests it is necessary. Sixty-five per cent of our patients complained of one or more side effects from the roentgen therapy, such as anorexia, nausea or vomiting. These symptoms were not severe and could be controlled by treating only two fields a day instead of three, and giving vitamin B_1 tablets, or thiamine chloride. Leukopenia was not common and never required cessation of roentgen therapy.

The number of series of roentgen treatments necessary must be determined by clinical follow-up and re-evaluation at frequent intervals. This is part of the educational program for the patients. A rising sedimentation rate and decrease in Weltmann coagulation band suggest activity of the growth of the granulations when associated with recurrence of the pain, stiffness and paravertebral muscle spasm. Successive series of roentgen treatments may be given with safety, provided the intervals between the series are sufficiently long. One hundred and twenty-six cases (78 per cent) in our analysis had one series, 27 cases (17 per cent) had two series, and 7 cases (5 per cent) were treated with three series (see Table VI).

TABLE VI

NUMBER OF SERIES OF ROENTGEN [illegible]

[illegible] cases, or [illegible]%, total dose in air 450 r
[illegible] cases, or [illegible]%, total dose in air [illegible]
1 case, total dose in air [illegible]
27 cases, or 17%, had two series [illegible]
[illegible]
7 cases, or 5%, had three series [illegible]
Number of series of treatments [illegible] determined by clinical re-evaluation at frequent intervals

Evidence of improvement under roentgen therapy and orthopedic care is summarized in Table VII. [illegible] per cent of the patients [illegible] that they were able to [illegible]

Table VII

EVIDENCE OF IMPROVEMENT

1. Allows orthopedic treatment to be tolerated.
2. Reduction of symptoms, especially pain, stiffness. 144 cases, or 90%.
3. Increase in spine motion and chest expansion. 91 cases, or 57%.
4. Relaxation of paravertebral muscle spasm. 102 cases, or 64%.
5. Sustained gain in body weight.
6. Rise in hemoglobin.
7. Decrease in sedimentation rate.
8. Weltmann coagulation band approximates normal.
9. Decrease in pulse rate.
10. Return to gainful occupation.

fore treatment. Thirteen patients who were bed-ridden for months and unable to work at all when therapy was instituted, returned to gainful occupation. This represents a cure rate of 8 per cent of the total treated and when added to the 68 per cent represents 76 per cent improved.

Seventy-two per cent of all treated cases showed a reduction of sedimentation rates after therapy. Table VIII shows the reductions in the 10 most improved patients.

Table IX shows the evidence of objective results obtained on follow-up records, separating the findings into stages of the disease. From this analysis it is obvious that the main effects of roentgen therapy are reduction of pain, stiffness, and paravertebral muscle spasm; spinal motion and chest expansion are increased, but all results are best in the earlier stages of the disease. The reduction of pain, stiffness, and paravertebral muscle spasm allows orthopedic correction of the otherwise inevitable deformities to be tolerated.

Table VIII

SEDIMENTATION RATES IN 10 IMPROVED CASES

72% of all cases showed reduction after roentgen therapy

Before 36/41/36/48/34/18/15/38/21/44
30/19/26/12/20/10/ 6/20/10/25

Weltmann Coagulation Band

Accurate determinations only on 40 cases, or 25%
23 determinations were below 6
17 determinations were above 6

Table IX

RESULTS

Reduction of pain, stiffness (144; 90%) of total 160
Stage 1—all 60 cases, or 100%
Stage 2—53 of 58 cases, or 91%
Stage 3—31 of 38 cases, or 82%

Increase in spine motion and chest expansion (91; 57%) of total 160
Stage 1—49 of 60 cases, or 81%
Stage 2—40 of 58 cases, or 69%
Stage 3— 2 of 38 cases, or 5%

Relaxation of paravertebral muscle spasm (102; 64%) of total 160
Stage 1—50 of 60 cases, or 83%
Stage 2—46 of 58 cases, or 79%
Stage 3— 6 of 38 cases, or 16%

13 patients were definitely rehabilitated and returned to gainful occupation—10 of these were in Stage 2. 3 were in Stage 3.

108 patients, or 68%, answered stating they could do more work than before treatment.

Table X gives the definite duration of follow-up records without recurrences since the last series of deep roentgen treatments. A follow-up letter was sent to each treated patient. One hundred and eighteen of the 160 treated patients replied. Ninety-nine cases, or 60 per cent, answered they were better; that is, free of pain, less stiff, and able to do more work. Nineteen patients replied that there had been a recurrence of the pain, stiffness, and fatigability and that they wanted more treatment.

Of the treated patients without recurrence, it is interesting that 20 per cent are symptom free for over one year since the last roentgen treatment.

Table X

FOLLOW-UP WITHOUT RECURRENCE

Time	No. Cases	Total Treated per cent
6 wk.–6 mo.	58	36
6–11 mo.	22	13
1– 2 yr.	10	6
2– 3 yr.	6	3
3 yr.	3	2
	—	—
	99	60

There has been definite recurrence and possibly advance of the disease in 19 cases, or 12%, of all treated cases.

DISCUSSION

Early diagnosis of ankylosing spondylarthritis offers seeming retardation of the progress of this disease if roentgen irradiation and orthopedic treatment are promptly instituted. Roentgen irradiation has a definite place in the treatment of this disease, but is not adequate by itself. The greatest value of roentgen therapy is that it allows orthopedic correction and prevention of the otherwise inevitable deformities to be tolerated because pain, stiffness, and paravertebral muscle spasm are reduced. Spinal motion and chest expansion are improved. Elevated sedimentation rates are usually reduced and Weltmann coagulation bands approximate normal. The pulse rate decreases, hemoglobin rises, and patients begin to gain weight. Some totally incapacitated patients can be rehabilitated by such combined therapy.

The pathological granulations of Marie-Strümpell disease are similar to the vascular granulations of other inflammatory reactions known to be radiosensitive. The question whether or not roentgen therapy arrests the production of this granulation before ankylosis develops cannot be answered. It is felt, however, that if roentgen therapy can be instituted early while there is still active granulation (and not complete ankylosis) the best results may be expected. Arrest of the production of the granulating pannus is not too much to hope for and roentgen therapy in carefully applied series as indicated might play a considerable part in this. If this is the mechanism of roentgen reaction, then arrest of early cases before disabling deformities occur should be possible by combined roentgen irradiation and orthopedic treatment. Such a regimen offers hope of more satisfactory results in Marie-Strümpell disease than either therapeutic measure used separately.

REFERENCES

1. Baker, L. D. Rhizomelic spondylosis; orthopaedic and roentgen therapy. *J. Bone & Joint Surg.*, 1942, *24*, 827–830.
2. Baker, L. D. Ankylosing spondylarthritis; Marie-Strümpell arthritis. Roentgen and orthopedic therapy. *South. M. J.*, 1943, *36*, 180–184.
3. Backberg, L. N. Differential Diagnosis of Chronic Arthritis. Second edition. Nutrition Research Laboratories.
4. Cecil, R. L. Text-Book of Medicine. Sixth edition.
5. Coates, V., and Delicati, L. Rheumatoid Arthritis and Its Treatment. H. K. Lewis & Co., Ltd., London, 1931.
6. Dawson, M. H. Chronic Arthritis. Loose Leaf Medicine, Thomas Nelson & Sons, New York, Vol. 5.
7. Forestier, J. Importance of sacro-iliac changes in early diagnosis of ankylosing spondylarthritis; Marie-Strümpell-Bechterew disease. *Radiology*, 1939, *33*, 389–402.
8. Fried, C. Röntgentherapie der Arthritis. *Strahlentherapie*, 1934, *49*, 634–675.
9. Hellebrand, A. Zur Arthritisbehandlung. *Strahlentherapie*, 1934, *49*, 676–677.
10. Kahlmeter, G. Roentgen treatment of arthritis. *Brit. J. Actinotherapy*, 1930, *5*, 93–95.
11. Kovacs, J. Surface temperature and minute blood vessels of skin in arthritis. *J. Am. M. Ass.*, 1933, *100*, 1018–1021.
12. Nissen, H. A., and Spencer, K. A. Sugar tolerance in the arthritic. *New England J. Med.*, 1934, *210*, 13–19.
13. Nissen, H. A., and Spencer, K. A. Arteriosclerosis in the arthritic. *New England J. Med.*, 1934, *210*, 92–97.
14. Nissen, H. A., and Spencer, K. A. Arthritis and systemic involvement as exemplified in group of dead arthritics. *New England J. Med.*, 1934, *210*, 147–149.
15. Pemberton, R. Arthritis and Rheumatoid Conditions. Second edition. Lea & Febiger, Philadelphia.
16. Scott, S. G. X-Rays in chronic rheumatic arthritis; diagnosis, prognosis and treatment. *Brit. J. Phys. Med.*, 1935, *10*, 127–128.
17. Smyth, C. J., Freyberg, R. H., and Lampe, I. Roentgen therapy for rheumatoid arthritis of the spine (Marie-Strümpell arthritis; spondylitis rhizomélique). *J. Am. M. Ass.*, 1941, *117*, 826–831.
18. Steinberg, C. L. Pathology of atrophic arthritis. *J. Lab. & Clin. Med.*, 1942, *27*, 435–443.
19. Swaim, L. T. Orthopaedic treatment of Strümpell-Marie arthritis. *J. Bone & Joint Surg.*, 1939, *21*, 983–991.
20. Toschke, G. Zur Röntgenbestrahlung von Gelenkerkrankungen. *Strahlentherapie*, 1941, *70*, 443–456.
21. Watt, W. L. Chronic infective and osteoarthritis; treatment by deep therapy. *M. Press*, 1942, *208*, 203–205.

DISCUSSION

Dr. Fred J. Hodges, Ann Arbor, Michigan. It has been a great pleasure to have the opportunity to read the paper by Dr. Hemphill and Dr. Reeves, and although my personal connection with the work published by the men from the University of Michigan is only slight, I have talked it over in detail with Dr. Lampe of our department who was one of the original publishers. He was gratified to learn of the intensive studies which have been carried on by these authors. There is little that I can add to what Dr. Hemphill has given you, except to compliment him on a very thoroughgoing analysis of the situation. His findings are very encouraging because the results are so tangible and so gratifying.

The dosage that we are giving at the present time is a little smaller and is carried out over a slightly longer period of time. We fractionate the dosage a little more minutely than he does; this is purely a matter of choice and one that has to do with our local situation. We have not been closely in touch with what the orthopedic department has been doing in the way of physical therapeutic measures as an associated method of treatment. The comments about opening the door to more elaborate orthopedic treatment are certainly very interesting and I am sure must be effective because oftentimes patients seen at the outset are in no condition to endure any sort of manipulation or exercise.

Dr. Lampe asked that I make this one comment or observation for him: Until this sort of work began, none of us realized the great frequency with which this disease is encountered in medical practice. We are seeing a great many more young people in the full vigor of life with the early, painful manifestations of this disease than were ever before believed to exist. I imagine that some little modicum of relief from extremely painful symptoms has started the parade and now such patients trickle in to us through our Arthritis Research Institute, where they are very carefully studied.

It is surprising to me that if this disease is so common as we now find it to be, we have not seen a great many more examples of the advanced stages which are so characteristic in roentgenological appearance. In any large hospital where numbers of patients with chronic illnesses are treated along with those who are acutely ill, it would seem that we would more often encounter the end-results than has been the case in the past. That raises the question as to the actual course of Marie-Strümpell disease once it starts. Perhaps all patients do not ultimately acquire the rigid bamboo type of spine that we display to students. It may be that the disease is in part self limited and that some people never go on to that far advanced stage. I don't know. In any event, this is an encouraging additional activity for radiation therapists and one which has certainly gone beyond the stage of unfounded hopefulness. It does produce results and it does put people back into active service for a varying length of time. Whether it can accomplish permanent cure will remain to be seen.

INFLUENCE OF BIOLOGICAL FACTORS ON THE FORM OF ROENTGEN-RAY SURVIVAL CURVES

EXPERIMENTS ON *PARAMECIUM CAUDATUM*

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As has been shown in experiments on *Eudorina elegans*, by Halberstaedter and Luntz,[7] the immediate lethal radium dose for different individuals of a biologically highly homogeneous population in standard conditions varies within a narrowly restricted range only.

In a related Volvox, *Pandorina morum*, we have found[8] that the immediate lethal roentgen-ray dose varies among different individuals of a mass culture in the range from 400,000 to 600,000 r, but is constant for all members of a single colony.

In order to obtain further information as to the radiobiological behavior of immediate or remote descendants of one parent, and in order to evaluate more closely the influence of biological factors on mortality curves, experiments on a more extensive scale were desirable. *Paramecium caudatum*, which has been used by us for many years for radiobiological studies,[1] was selected for this purpose.

TECHNIQUE

Roentgen Tube. The irradiation was carried out by means of a demountable roentgen tube, which was operated at 35 kv. and a current of 20 ma., using a copper anticathode. The window consisted of an aluminum foil of 30μ thickness. Absorption analysis showed that the rays, which penetrated through the window foil and through the mica cover-glass, were mainly copper K rays. The intensity of the roentgen rays was about 90,000 r per minute at the distance of the irradiated subject.

Test Organism. Paramecium caudatum was cultivated in a mixture composed of two parts of a standard hay infusion and one part of soil extract (prepared according to Pringsheim[12]). *Bact. coli* were added to this medium for nutriment.

The cultures were maintained in a thermostat at 25° C. In these conditions cell division occurred at intervals of eight to ten hours. The stock cultures were maintained in Boveri dishes in 15 cc. of nutrient medium and were transferred fortnightly.

Irradiation was carried out in small drops of water under mica slips of known thickness. The volume of the drop was between 1.5 and 2.0 mm.[3] and its depth 0.2–0.3 mm. As a protection against evaporation the drops were covered with a larger drop of paraffin oil and fixed as hanging drops by means of vaseline in the chamber of a hollow ground glass slide.

Preliminary experiments showed that specimens of *Paramecium caudatum* are able to multiply normally within the drop of the size employed in the irradiation experiments, and therefore that the paramecia are not affected by the smallness of the drop during the brief interval of time required for irradiation.

The radiation was applied in successive steps of 50,000 or 100,000 r, and the organisms were examined at low magnification after each stage of irradiation.

Doses of 100,000 r were without visible effects. The action of irradiation on the organisms first becomes visible in the alteration of the manner of their movement. This change becomes clearly manifested when one-half of the immediate lethal dose (I.L.D.) has been applied. Ciliar movement then loses its normal coordination, the cilia fail to move in unison, and the paramecia swim irregularly backward and forward. With greater doses movement is brought to a complete standstill, and after a brief time

cytolysis always occurs. Complete cessation of movement therefore serves as an indication of the impending death of the organism. The immediate lethal dose is accordingly defined for *Paramecium caudatum* as that dose which produces complete cessation of motility within ten to fifteen minutes after irradiation.

It was necessary to determine whether roentgen irradiation with the doses employed by us causes alterations in the nutrient medium, which have a toxic effect on the paramecia.

Piffault,[11] Taylor, Thomas and Brown,[13] and others, have shown that a large dose of roentgen rays may produce products, probably peroxides, toxic for *Paramecium*. The culture medium employed by us, even after irradiation with doses up to 1 million roentgens failed to exert a toxic effect on the paramecia.

The main experiments fall in two groups.

1. *Clone* experiments.
   These were carried out on cultures three or more days old, i.e. on offspring remote from the common parents by at least six generations.

2. *Family* experiments.
   These comprised individuals remote from the common parents by no more than three generations. The number of specimens tested in any one of these experiments was consequently never greater than eight.

In the clone experiments a number of randomly sampled members of a clone were transferred from a culture, three or more days old, by means of a pipette, into drops prepared as has been described. The number of specimens irradiated in any one of the clone experiments was not greater than twelve.

In the family experiments, a single member of a clone was removed and cultivated in a hollow ground glass slide in 0.7 cc. of the culture medium at 25° C. When 4–8 individuals had formed, irradiation was applied as described above. The number of individuals in any family so prepared was 8 or less.

RESULTS

1. *Clone Experiments*. The lethal dose for different individuals of a single clone was found to be variable. Application of 200,000 r caused death in a small percentage of the irradiated population. With increase in the dosage this percentage rises. At 600,000 r, almost all the irradiated specimens die. All survivors of this treatment died after the dcse was increased to 700,000 r. The dose which produces a 50 per cent mortality rate lies between 350,000 and 400,000 r. The findings are given in Table 1, which presents the full data for 112 typical irradiation trials, comprising a total of 750 organisms. It is clear from the reported results that different members of a clone, irradiated in the same drop, are killed at different dose levels, and further, that the distribution of the immediate lethal dose values among the individuals of a drop varies from one drop to another.

Figure 1 shows the results of these experiments plotted as a survival curve. The shape of the curve (unbroken line) is typi-

Table I

PERCENTAGE MORTALITY AFTER IRRADIATION

100,000 r		200,000 r		300,000 r		400,000 r		500,000 r		600,000 r		700,000 r	
M.C.*	F.†	M.C.	F	M.C.	F.	M.C.	F.	M.C.	F.	M.C.	F.	M.C.	F.
0	0	3.0	6.6	32.2	39.4	73.5	77.7	93.8	96.3	99.0	99.1	100	100

* M.C.=Mass culture, 750 specimens in all.
† F.=107 families, 4–8 specimens in each.

cally sigmoid and corresponds to the sigma curve obtained by different investigators for biological materials of a wide variety of

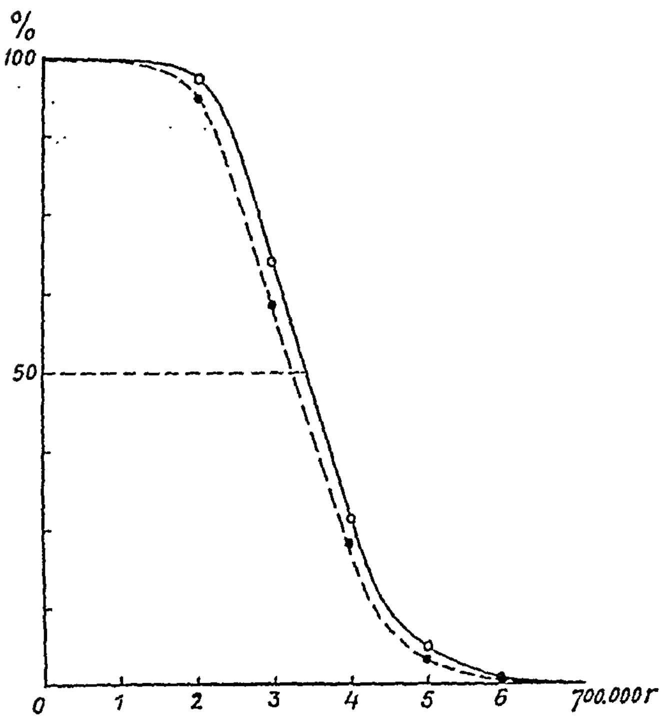

Fig. 1

types; e.g., Crowther[3] with *Colpidium colpoda;* Holweck and Lacassagne[9] with *Saccharomyces;* Zuppinger[14] with bean root and *Ascaris* eggs; Braun and Holthusen[2] with eggs of *Ascaris* and *Drosophila.*

2. *Family Experiments.* In these experiments different immediate lethal doses were found for different drops. The immediate lethal doses must therefore be variable from family to family. The range of the variations was the same as that encountered previously in a clone. All individuals of any given single family, however, in fundamental contrast to the findings for individuals in a clone, die at the same dose level. Differences in radiosensitivity are therefore inter- rather than intra-familial.

The results of trials comprising 107 families have been plotted in Figure 1 as a survival curve, the family being regarded for the purposes of this curve as a single unit independently of the number of individuals of which it is in fact composed (broken line, Fig. 1). The plotted curve possesses, as was to be expected, the same form as the curve found for clones.

The results of 20 family irradiation experiments are set forth in detail in Table II. Each horizontal column of the table shows survivals within a family at different doses. The dose which produces death of all irradiated specimens within a single family is sharply marked off from a dose level immediately below, which is uniformly non-

Table II

EXPERIMENTS ON FAMILIES

No.	Number of Individuals	Number of individuals alive after a dose of 200	250	300	350	400	450	500	550	600	650 thousand r
1	8	0									
2	5	5	0								
3	6	6	6	0							
4	8	8	8	0							
5	7	7	7	7	0						
6	8	8	8	8	0						
7	8	8	8	8	8	0					
8	6	6	6	6	6	6	0				
9	7	7	7	7	7	7	0				
10	8	8	8	8	6	6	0				
11	4	4	4	4	4	4	4	0			
12	5	5	5	5	5	5	5	0			
13	8	8	8	8	8	8	8	8	0		
14	4	4	4	4	4	4	4	4	4	0	
15	6	6	6	6	6	6	6	6	6	6	0

lethal for all individuals of the same family.

In order to meet the objection that this result may have been affected by the fact that, in the technique employed, only a small number of individuals had been irradiated in a single trial, an experiment with identical technique was run on randomly selected members of a clone. The results of this check are shown in Table III. Here again, each horizontal column summarizes a single simultaneous irradiation experiment. It is evident from the tabulated results that despite the use of small samples randomly selected, members of a clone, in contradistinction to members of a single family, are generally found to die at different dose levels.

Deviations from the behavior pattern, which has been described, were exceedingly rare.

TABLE III

EXPERIMENTS ON CLONES

No.	Number of Individuals	Number of individuals alive after a dose of 200	300	400	500	600	700 thousand r
1	6	4	0				
2	5	4	4	0			
3	8	8	5	0			
4	4	4	4	1	0		
5	4	4	2	2	0		
6	4	4	4	1	0		
7	5	5	5	3	0		
8	6	6	6	3	0		
9	7	7	5	1	0		
10	7	7	6	2	0		
11	4	3	3	2	2	0	
12	6	6	6	3	3	0	
13	6	6	3	2	1	0	
14	6	6	5	3	2	0	
15	7	7	6	5	1	1	0

DISCUSSION

The fact that simultaneously irradiated different individuals of one species do not die with the same roentgen-ray dose was originally ascribed to individual differences in radiosensitivity. Dessauer,[5] on the other hand, attempted to explain this phenomenon in purely physical terms.

From considerations on the discontinuous random distribution of absorption in an object irradiated with roentgen rays, Dessauer, Blau and Altenberger[4] were able to construct curves based on probability calculations, which are similar in shape to the mortality curves experimentally established for a variety of biological objects. This finding induced Dessauer to formulate his "point heat" theory.

Crowther, who has treated this problem extensively, similarly based his considerations primarily on the random discontinuous nature of roentgen-ray absorption. The prerequisite of effective radiation action on biological systems, according to Crowther, is the "hit" of a sensitive structure in the cell by radiation. He defines "hit" as the production of a pair of ions within a sensitive zone in the cell.

It has been pointed out, in criticism of these attempts, that the experimentally derived mortality curve could also be adequately explained in terms of biological variation alone. The mortality curve, accordingly, could be regarded simply as a curve of biological variation.

In the case of sigma-shaped mortality

curves, the latter interpretation must be regarded as acceptable, since differentiation in this case between the relative validity of the physical and the biological interpretation is not possible. Crowther himself, in his critical examination of his experiments with *Colpidium colpoda*, made the following statement: "If we assume that on an average a Colpidium requires a dose of 3.26 mc. to produce immediate death, but that owing to biological variations among the specimens some individuals require more and some less than the average, then, if these variations from the mean follow the usual law of errors, we should get a survival curve (the measure of precision being suitably adjusted) which would not be distinguishable from the experimental curves, within the limits of accuracy of these experiments. The difficulty is due to the large value of n in these experiments." (n = number of hits.)

Meissner[10] has modified mortality curves calculated from physicomathematical theory on the basis of a Poisson distribution. It is not readily evident, however, whether and to what degree it is possible to determine the rôle played by the biological factor in the form of an experimentally determined S-curve of roentgen-ray damage. If the mortality curve calculated for a given number (n) of hits is modified in accordance with the method suggested by Meissner, a curve is obtained which is identical with that calculable for a different value of n *without* reference to biological variation (Glocker[6]).

These objections do not hold, however, for exponential mortality curves where $n=1$, such as have been obtained, for instance, in irradiation experiments on bacteria and viruses.

In the present investigation we have attempted to assess the significance of the biological factor experimentally by tests of the effect of roentgen rays on a selected biological species. Specimens of *Paramecium caudatum* have been subjected to various doses of roentgen rays under uniform experimental conditions, and by these means the immediate lethal dose for individuals irradiated has been determined. In simultaneous irradiation of numerous paramecia in the same drop and under the same conditions different behavior is observed among individuals of clones or of families. Members of clones die at different roentgen-ray doses, members of families die at the same time.

In view of the reproducibility of this result with rare exceptions in an extensive series of experiments, it is valid to conclude that for *Paramecium caudatum*, at least, biological variability plays a significant rôle in determining the shape of the mortality curve. The extent of this influence requires further experimental elucidation. It is our belief, however, that the test method employed by us renders the influence of biological variability on roentgen-ray mortality curves accessible to experimental trial.

SUMMARY

1. Experiments have been carried out to determine the difference in roentgen-ray susceptibility between immediate (family) and remote (clone) descendants of a single parent.

2. The immediate lethal dose of roentgen rays for different individuals of *Paramecium caudatum* in a mass culture varies between 200,000 and 700,000 r. The immediate lethal dose for different families of *Paramecium caudatum* also varies between 200,000 and 700,000 r. The roentgen-ray mortality curve is sigmoid.

3. Irradiated in the same drop, members of a clone died at different roentgen-ray doses; under the same conditions, members of a family always died at the same dose.

4. The different behavior pattern of specimens of a clone or of a family, respectively, when simultaneously irradiated can only be explained on the basis of biological variability, the variability in radiosensitivity being greater between members of a clone than between members of a family.

REFERENCES

1. Back, A. Sur un type de lésions produites chez *Paramaecium caudatum* par les rayons X. *Compt. rend. Soc. de biol.*, 1939, *131*, 1103–1106.
2. Braun, R., and Holthusen, H. Einfluss der Quantengrösse auf die biologische Wirkung verschiedener Röntgenstrahlenqualitäten. *Strahlentherapie*, 1929, *34*, 707–734.
3. Crowther. *Proc. Roy. Soc., Ser. B*, 1926, *100*, 390.
4. Dessauer, Blau, and Altenberger. *Ztschr. f. Phys.*, 1923, vol. *12*.
5. Dessauer, Friedrich, Editor. Zehn Jahre Forschung auf dem physikalisch-medizinischen Grenzgebiet. Georg Thieme, Leipzig, 1931.
6. Glocker, R., and Reuss, A. Ueber die Wirkung von Röntgenstrahlen verschiedener Wallenlänge auf biologische Objekte. *Strahlentherapie*, 1933, *46*, 517–528.
7. Halberstaedter, L., and Luntz, A. Die Wirkung der Radiumstrahlen auf Eudorina elegans. *Arch. f. Protistenk.*, 1929, *68*, 177–186. *Ibid.*, 1930, *71*, 295.
8. Halberstaedter, L., and Back, A. Effect of x-rays on single colonies of Pandorina. *Brit. J. Radiol.*, 1942, *15*, 124–128.
9. Lacassagne. *Compt. rend. Acad. d. sc.*, 1930, *190*, 524.
10. Meissner. Quoted by Zuppinger.[11]
11. Piffault, C. Action des rayons X sur l'eau et ses conséquences. *Compt. rend. Soc. de biol.*, 1939, *130*, 43–44.
12. Pringsheim. *Ztschr. f. Biol. d. Pflanzen*, 1921, *14*, 283.
13. Taylor, Thomas, and Brown. *Physiol. Zool.*, 1933, *6*, 467.
14. Zuppinger, A. Radiobiologische Untersuchungen an Ascariseiern. *Strahlentherapie*, 1928, *28*, 639–758.

CALCULATION OF RADIUM DOSAGE ALONG THE LONGITUDINAL AXIS OF LINEAR SOURCES*

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IN PREVIOUS articles,[12,13] the results of calculations of radium dosage for linear sources in gamma roentgens were presented. The problem of calculating the dose beyond the end of a linear source along a line continuous with the longitudinal axis of the linear source (such as P_2 in Fig. 1) was, however, not considered. In some cases, it is necessary to know the dose along this axis, at least approximately. For example, in the conventionalized arrangement of the intrauterine radium capsules in tandem, the external cervical os and the rectal mucosa point lie on the longitudinal axis of the linear radium sources. The rectal dose is of considerable importance in the treatment of cancer of the cervix and, in some cases, may be the factor limiting the total amount of treatment.

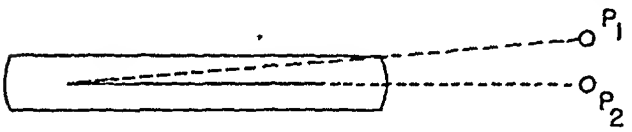

FIG. 1. P_2 is a point on the longitudinal axis of a filtered linear source. P_1 is a point a short distance from the longitudinal axis. To reach P_2, radiation traverses the thickness of container wall at the end. To reach P_1, radiation must pass obliquely through a considerable thickness of the side wall of the container.

It has been more or less assumed that the amount of radiation beyond the end of a tube is small and may be neglected for practical purposes.[9] This is certainly not generally true. Experimental investigations of the "end effects" of radium capsules by autoradiographic methods have been made by Mazerès,[8] Guében,[3] and Mayneord.[6] The radiographs show a zone of considerable intensity along the longitudinal axis, surrounded by a ring of distinctly less intensity. This result was anticipated by a consideration of the paths taken by radiation to reach a point on the central axis (P_2, Fig. 1) and a point a short distance away from the central axis (P_1, Fig. 1). To reach P_2, the radiation traverses a certain length of radium salt and the thickness of the container at the end of the capsule. To reach P_1, the radiation must pass obliquely through a considerable length of container material on one side of the capsule. Since the absorption by radium salt as packed within tubes is less than the absorption by metals like platinum (about one-tenth), the amount of radiation absorbed by the tube itself is considerably greater for rays reaching P_1 than for those reaching P_2 and the intensity at P_2 will therefore be greater than the intensity at P_1. The width of this region of relatively high dosage on the longitudinal axis depends on the diameter of the tube and the distance from the end of the tube. The existence of this region of high intensity is of particular significance when the dosage at points of maximum tolerance is to be calculated.

Experimental determination of radium dosage along the longitudinal axis by ionization methods is extremely difficult because the size of the smallest available ionization chamber is large compared to the region in question. Autoradiographic methods are in general not satisfactory because of the difficulty in obtaining consistent results and because of the uncertainty as to the relationship of blackening to the intensity of the primary gamma radiation. The isodose curves usually given for linear sources do not show the region of relatively high dosage along the longitudinal axis. The isodose curves for the (unspecified) linear source investigated by Guében[3] and the qualitative isodose curves in a diagram published by Tod and Meredith[11] were the only ones found which showed the outward

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bulging along the longitudinal axis and its immediate neighborhood.

A mathematical method to calculate the dose on the longitudinal axis was described by Sievert.[10] Mayneord and Honeyburne[7] also calculate dosage on this axis by assuming the linear source to be represented by multiple point sources. The most uncertain factor in these calculations is the absorption in the radium salt itself. This will vary with the closeness of packing and the exact source (Mayneord,[5,6] Goldhaber and Griffith[2]) shows a difference of about 10 per cent. In view of the errors of both methods, this is surprisingly close agreement. The method of Sievert was simplified so that the final result is obtained by multiplying the dose for an unfiltered linear source by a filtration factor depending on the thickness of the container at the end of the capsule or needle.

The dose for the unfiltered source is

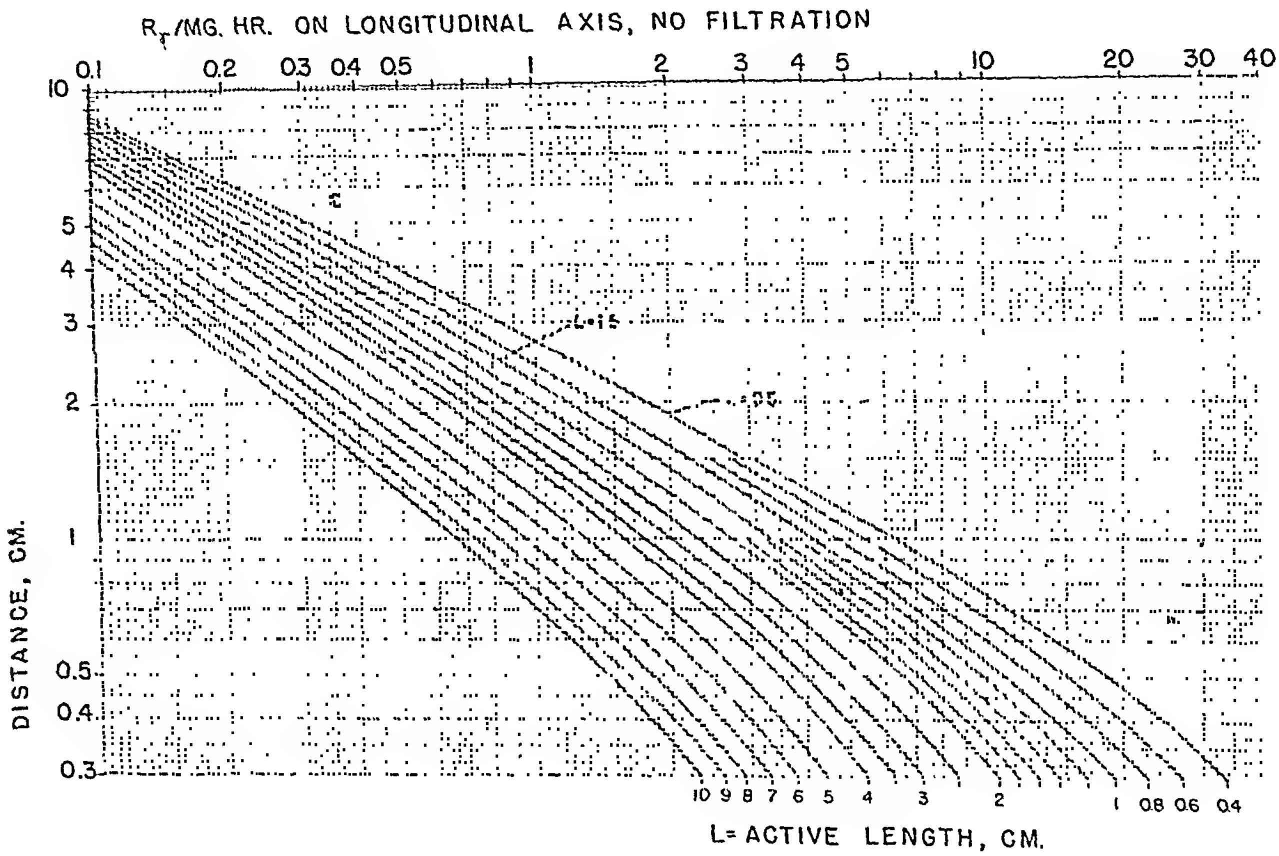

Fig. 2. Graph giving the dose at points along the longitudinal axis of an unfiltered linear source. Each curve corresponds to a given active length. The vertical coordinate is the distance from the point at which the dose is to be calculated to the near (active) end of the linear source. The horizontal coordinate is the dose in gamma roentgens per milligram-hours.

chemical structure and degree of purity of the radium salt used. The results of these calculations can therefore be only approximate unless these factors are known, but the degree of accuracy is probably sufficient for clinical purposes. Benner[1] claims to have confirmed the validity of the Sievert formulae by experimental means. Comparison of the figures given below with the results of ionization methods at points on the longitudinal axis some distance from the found from Figure 2. Each curve of the family of curves of this graph represents a different active length. The vertical coordinate is the distance between the point at which the dose is desired and the near (active) end of the linear source. The dose in gamma roentgens per milligram-hour is read on the horizontal axis. The data were plotted on logarithmic graph paper in order to include a large range with the same accuracy throughout.

The container material was assumed to be platinum. For other materials, their platinum equivalents may be used. The data for Figure 3 were plotted on semilogarithmic graph paper. On the horizontal axis is found the thickness of the container

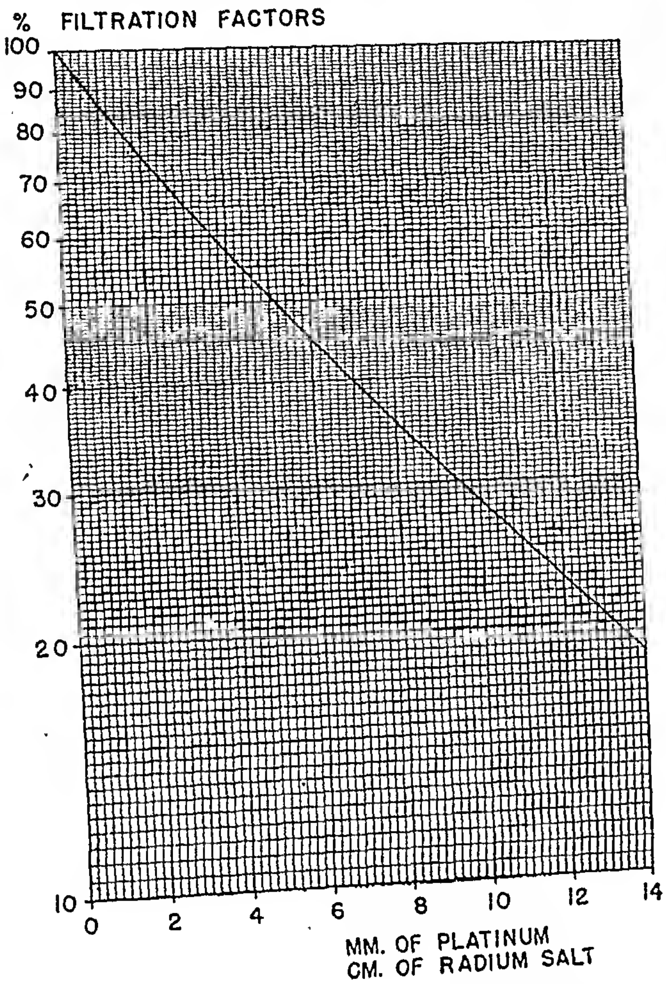

Fig. 3. Graph for filtration correction factors in percentage of the value for an unfiltered source. The thickness of the end of the capsule in millimeters of platinum (or platinum equivalent) is found on the horizontal axis and the filtration factor on the vertical axis. If the ray which passes along the longitudinal axis must pass through radium salt within another capsule, the number of centimeters of radium salt traversed is added to the number of millimeters of the platinum traversed to find the suitable factor.

wall at the end of the linear source in millimeters of platinum. The filtration correction factor, in per cent, to multiply the dose from the unfiltered source, as found from Figure 2, is read on the vertical axis.

Example 1 (Fig. 4). Given a linear source with active length 2.0 cm., an overall length of 2.4 cm., and filtration of 2 mm. of platinum at each end.

To find the dose per milligram-hour at a point 4.0 cm. from the active end of this source along the longitudinal axis.

Active length $=L=2.0$ cm.

Distance to (near) end $=d=4.0$ cm.

If the source were unfiltered, from Figure 2, we find that the

Dose per milligram-hour $=0.33$ gamma roentgen.

Filtration at end $=t=2$ mm. of platinum.

From Figure 3, for this thickness of platinum, the filtration correction factor is 75 per cent.

For the given filtered source, then,

Dose $=$ dose for unfiltered source $\times$ filtration factor.

Dose per milligram-hour $=(0.33)(0.75)$
$=0.248$ gamma roentgen.

To calculate the dose from a linear source at a point on its longitudinal axis when another linear source is present on the same line between the source and the point in question, as in a coaxial tandem arrangement of capsules, the procedure is similar to the above. The only difference is that, in obtaining the filtration factor, the additional filtration of the ends of the intervening capsule and of its radium salt must be included. By pure coincidence, it happens that the absorption coefficient per millimeter of platinum is the same as the absorption coefficient per centimeter of radium salt (see later). The filtration factor in this type of case may therefore be deter-

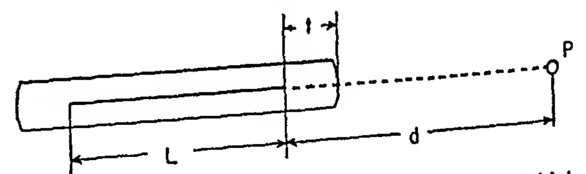

Fig. 4. L equals active length in cm.; t equals thickness of end of capsule in mm. of platinum; d equals distance to active end of linear source in cm.; P is point at which the dose is to be calculated.

mined from the same curve (Fig. 3) as in the previous case. The number of millimeters of platinum is added to the number of centimeters of radium salt present on the central axis between the active end of the original linear source and the point at

which the dose is desired. An example will make clear how simple this procedure is.

Example 2 (Fig. 5). Given a linear source with active length 2.0 cm. and filtration at the end equivalent to 2.0 mm. platinum. Between this capsule and the point at which the dose is desired is another capsule in coaxial tandem arrangement, with an active length of 2.5 cm. and filtration at each end equivalent to 2 mm. of platinum.

To find the dose at a point 4.0 cm. from the active end of the original capsule along its longitudinal axis.

For an unfiltered source with active length 2.0 cm., at a distance of 4.0 cm. from its end,

P = number of milligram-hours;
L = active length in centimeters;
v = linear absorption coefficient of the radium salt;
u = linear absorption coefficient of container material;
d = distance to near (active) end of the linear source;
t = thickness of container wall at end of tube;

$$f(x)=\int_x^\infty \frac{e^{-x}}{x^2}\,dx$$

To convert the Sievert unit of dosage into gamma roentgens, the figure 9.0 was used (Neary,[9] Mayneord and Honeyburne[7]).

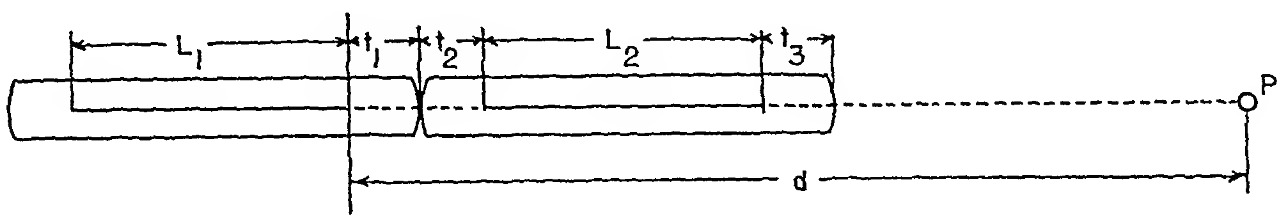

FIG. 5. Another capsule, L_2, in coaxial tandem arrangement. The filtration correction factor is obtained by adding, t_1, t_2 and t_3 in mm. to L_2 in cm. The filtration factor is found from Figure 3 for this summated "thickness."

we find from Figure 2, as in the previous example, that

Dose per milligram-hour = 0.33 gamma roentgen.

To obtain the filtration correction factor, the thickness of all material between the (active) end of the unfiltered source and the point P must be added—mm. of platinum plus cm. of radium salt.

$$t_1+t_2+t_3+L_2=2.0+2.0+2.0+2.5=8.5$$

From Figure 3, the filtration factor for this "thickness" is 33.5 per cent.

Dose per mg-hr. of the original capsule
$=(0.33)(0.335)$
$=0.111$ gamma roentgen.

Of course, if the dose at the same point per milligram-hour of the intervening capsule is required, this is calculated as in Example 1.

MATHEMATICAL CONSIDERATIONS

The formula given by Sievert[10] for dosage along the central axis is

$$\text{Dose}=\frac{P}{L}\,e^{vd-ut}v[f(vd)-f(vd+vL)].$$

The unit in which the dose is expressed is the amount of radiation at 1 cm. from a 1 mg. point source of unfiltered radium element in 1 hour.

The figure 0.15 per cm., determined by Sievert[10] for 90 per cent water-free radium sulfate moderately well packed was used for v.

The mean linear absorption coefficient of platinum for gamma radiation filtered by 0.5 mm. point was taken as 1.5 per cm. since this seems to be the best average value available at present.[7,8] In constructing the graph of Figure 3, the decrease in absorption coefficient with increasing thicknesses of platinum was included by utilizing the slopes of the curve calculated by Sievert[10] from experimental values of Kohlrausch.

The table of integrals was extrapolated for a short distance to include points close to the end of the linear source. Secondary beta radiation from the metallic container does not contribute any significant ionization beyond 2 or 3 mm. from the surface of a capsule.[2,4]

SUMMARY

The results of calculations of radium dosage in gamma roentgens along the longitudinal axis of linear sources are presented. The method used was that described by Sievert but substituting a more recent value for the absorption coefficient of

platinum. The accuracy of these calculations is limited by uncertainties in the values of the absorption coefficients, but experimental methods for determination of dosage in this region are as yet unsatisfactory. The usual isodose curves are either inaccurate or omit entirely the dose along the longitudinal axis. The intensity of radiation along this axis is greater than the intensity in the immediate surrounding region and should not be neglected.

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REFERENCES

1. Benner, S. Intensity distribution around radium preparations. *Acta radiol.*, 1934, *15*, 291–303.
2. Goldhaber, G., and Griffith, H. D. Valve amplifier for the detailed study of radium isodose curves. *Brit. J. Radiol.*, 1933, *6*, 656–665.
3. Guében, G. La répartition du rayonnement autour des tubes de radium. *Acta radiol.*, 1930, *11*, 237–247.
4. Hamann, A. Interstitial radium dosage expressed in roentgens. Am. J. Roentgenol. & Rad. Therapy, 1940, *44*, 276–286.
5. Mayneord, W. V. Measurement in "r." units of the gamma rays from radium. *Brit. J. Radiol.*, 1931, *4*, 693–710.
6. Mayneord, W. V. Distribution of radiation around simple radioactive sources. *Brit. J. Radiol.*, 1932, *5*, 677–716.
7. Mayneord, W. V., and Honeyburne, J. Physical study of intracavitary radium therapy. Am. J. Roentgenol. & Rad. Therapy, 1941, *45*, 235–249.
8. Mazerès. Sur le rayonnement primaire gamma autour d'une source linéaire de radium. *J. de radiol. et d'électrol.*, 1926, *10*, 159–163.
9. Neary, G. J. Physical aspects of intracavitary radium treatment of carcinoma of the cervix uteri. Part 2. *Brit. J. Radiol.*, 1943, *16*, 263–269.
10. Sievert, R. M. Die Intensitätsverteilung der primären γ-Strahlung in der Nähe medizinischer Radiumpräparate. *Acta radiol.*, 1922, *1*, 89–128.
11. Tod, M. C., and Meredith, W. J. Dosage system for use in the treatment of cancer of the uterine cervix. *Brit. J. Radiol.*, 1938, *11*, 809–823.
12. Wolf, B. S. Radium dosage for linear sources. Am. J. Roentgenol. & Rad. Therapy, 1943, *50*, 400–405.
13. Wolf, B. S. Radium dosage for linear sources; table and nomogram. Am. J. Roentgenol. & Rad. Therapy, 1944, *51*, 747–757.

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Twenty-eighth Annual Meeting: 1945, canceled.

EDITORIALS

WARTIME RADIOLOGY AND PEACETIME PROBLEMS*

THE Surgeon General of the Army has assigned me to the pleasant duty of representing the Medical Department, Army of the United States, at this meeting and I am glad to have a share in this recognition of radiology's importance in military medicine. I consider it a high honor, not only to have the rare privilege of representing the Office of The Surgeon General but also to be here as the personal representative of the man who holds that office, Major General Norman T. Kirk, and I am happy to bring you his cordial greetings and best wishes for a successful meeting.

It may be fitting at this time to review the measures that became necessary in securing an adequate personnel for the radiologic service of a vast and rapidly expanding army and to consider the effect on radiologic standards that is likely to follow demobilization of this personnel.

When it became apparent that this nation's peace and safety were menaced by the Axis powers, the United States began to expand its military forces as a defensive measure. This increase entailed, of course, a corresponding increase of the Medical Department of the Army including the radiologic service, and enlistment of radiologists was invited. But the response was slow and insufficient, partly, no doubt, because it was widely believed that this country would escape involvement in the war and that the need of the Medical Corps for more radiologists could be regarded as theoretical rather than actual or at least as not pressing. Great camps were established and large hospitals erected to care for the trainees. For these hospitals there were not enough trained radiologists, but radiologic service had to be given. Young medical officers who had had only limited experience in radiology or even those who merely showed an interest in the specialty were assigned to this work. By study of texts and journals, by conferences with civilian radiologists located nearby and by cautious trial and error, most of these men gradually acquired enough skill to render excellent service. Indeed, some of them applied themselves with such enthusiasm and diligence that they received high commendation, earned advancement in rank and successfully passed the examination prescribed by the American Board of Radiology.

Then came Pearl Harbor! We were at war, and the demand for radiologists in the Army was plainly not only real but urgent. Medical Reserve Officers who had not previously been called were ordered to duty, but their number was too small to have any substantial effect, and chief dependence had to be placed on voluntary enlistments to fill required quotas. Notwithstanding the thorough publicity given the emergency and efforts to meet it by direct appeals and indirectly suggestive questionnaires, not enough radiologists could be obtained. Apparently at that time the older radiologists had a proportionately larger representation in the Army than the younger men, but it should not be inferred that the latter group were solely responsible for the disparity. Certainly all reasonable civilian needs had to be considered and hospitals and other institutions had a valid claim to an irreducible mini-

* Presented at the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, Chicago, Ill., Sept. 24–29, 1944.

mum of radiologic service. The difficulty arose in setting that minimum fairly in each community and thus preventing an abuse of privilege. Whatever the causes may have been, there was a serious and continuing shortage of competent radiologists in the Medical Corps, and something had to be done about it quickly.

Accordingly the Surgeon General, after careful consideration and with the approval of his advisers, determined to institute a program of intensive training of medical officers selected for radiologic service. Only medical officers who had some knowledge of radiology or showed a keen interest in it were chosen for training and the course of instruction was thoughtfully planned as to its length, breadth and obligatory requirements. Under the able supervision of Colonel A. A. de Lorimier the candidates were given six weeks basic training at the Army School of Roentgenology, which at first was located in Washington but later was moved to Memphis. Colonel de Lorimier arranged an excellent curriculum which consisted largely of didactic and practical training in the fundamentals of radiology. His school has recently lengthened its course to twelve weeks and more clinical instruction has been added. In addition to the Army School of Roentgenology an advanced course in radiology was established at the Mayo Foundation at which the student officers were given twelve weeks intensive training. Those chosen to attend the advanced course were selected from among those showing unusual aptitude while in attendance at the Army School of Roentgenology or from those who had some previous experience with, or training in, the use of roentgen rays. This course consists almost wholly of practical roentgenographic interpretation and roentgenoscopy. I have had personal contact with all those in attendance and I have found that practically all of the men who have been detailed to the Mayo Foundation for training seemed to have superior intelligence and zeal and a proper sense of their responsibility.

On satisfactory completion of one or both of these courses these brevet radiologists have been assigned to duties commensurate with their ability as nearly as that could be determined. Most of them were assigned to stations as assistants to experienced radiologists who had been given more responsible posts. That these novices have made good I can aver from direct and wide personal observation. In the performance of my duties as the Senior Consultant in Radiology in the Office of The Surgeon General I have visited the radiologic departments of more than two hundred Army hospitals all over the United States, and everywhere I went I was gratified to find that the intensively trained assistants were doing their work with remarkable efficiency. In a few instances that I recall with pleasure the assistant, who as a civilian had no experience with roentgenology, had become as proficient in diagnosis as a veteran radiologist. That the novices are doing their work well is not only pleasing but important. In simple fairness, I want also to pay deserved tribute to the veteran experienced radiologists, for their leadership and ability has placed the radiologic work in the army on a high plane. In fact, in several Army hospitals the radiologic work is on a par with that done in our most renowned civilian institutions. A medical consultant in one of the service commands told me recently that when he makes his initial inspection of a hospital he invariably visits first the radiologic department and the clinical laboratory in order to observe the quality of their work, for he is aware that the efficiency of the general diagnostic work of the hospital will be no higher than the ability of those responsible for the roentgenologic and clinical laboratory reports.

At present there are in the Army approximately 450 radiologists who have been certified by the American Board of Radiology and possibly 750 whose roentgenologic experience has been obtained in the Army, or who have had from six months to two years' training before entering the Army.

In the Army every effort has been made to assign men qualified in radiology to a radiologic department. Except for good and sufficient reasons every certified radiologist is doing radiologic work. Among the exceptions are those in the Regular Army who are expected to take administrative positions during war time and other officers who have requested similar or other assignments for various reasons.

More than 50 per cent of applicants certified at the latest meeting of the American Board of Radiology (February, 1944) were in Army uniform. Of these a small number had just entered the Army after completing three years of graduate instruction and a small number had received all their experience and training in the Army. A majority, however, had had from six months to two years' training in civilian institutions followed by more or less training or experience or both in the Army. This sample speaks well not only for the men chosen to do radiologic work in the Army but also for the opportunities afforded them by the Army.

At the war's end approximately 400 noncertified military radiologists, trained during and for the emergency, will face adjustment to peacetime conditions. These colleagues of ours may possess extraordinary skill in the radiology of military injuries and diseases and their resulting complications and sequelae and of certain diseases seen chiefly in foreign lands. On the other hand, they will be deficient or totally lacking in experience with radiation therapy and many general radiologic problems including a vast array of domestic diseases, especially those that are degenerative and chronic. No doubt most of these men will elect to continue in the practice of radiology either immediately or after further preparation.

A preliminary study of a survey by Lieutenant Colonel Harold C. Leuth* indicates that approximately half of the medical officers in the armed forces will desire further graduate training and that most of this group will seek certification by specialty boards. I am sure you will be interested to know that they suspect that more men will indicate their desire to seek certification by the specialty boards than are now certified by all of the boards up to this date. That does not mean that when the War is over and they are ready to go home they will then be willing to continue, but at the moment they think so. This estimate appears to be well based and acceptable as fairly representing the aims and hopes of the noncertified radiologists in the armed forces. It will be our privilege, then, as individuals and through our teaching institutions and radiologic organizations to help these men secure posts where their talents will be of greatest service and foster their ambition to complete their training so that they may be recognized and certified as specialists.

From all indications there will be no lack, or at least no prolonged lack, of employment after the war for practitioners of radiology, whether fully or only partly skilled. A large standing Army and a vast Navy will retain many emergency radiologists in service. Those who come out will find the people keenly conscious of health and disease, demanding examination or treatment with every modern agent, including roentgen rays and radium. Radiologists in great new hospitals, in new medical groups and in individual practice will be calling urgently for assistants. If the post of assistant is not acceptable, any demobilized medical officer has the right, as a physician, to engage in the independent practice of radiology, whatever his degree of skill in that specialty may be, and a united profession will vigorously oppose any curtailment of that right. In view of these considerations it seems unlikely that radiologists presently coming out of military service will have any reason to worry over their economic prospects.

Less easy to solve will be the problem of

* Leuth, H. C. Future educational objectives of medical officers. *J. Am. M. Ass.*, 1944, *125*, 1099–1103.

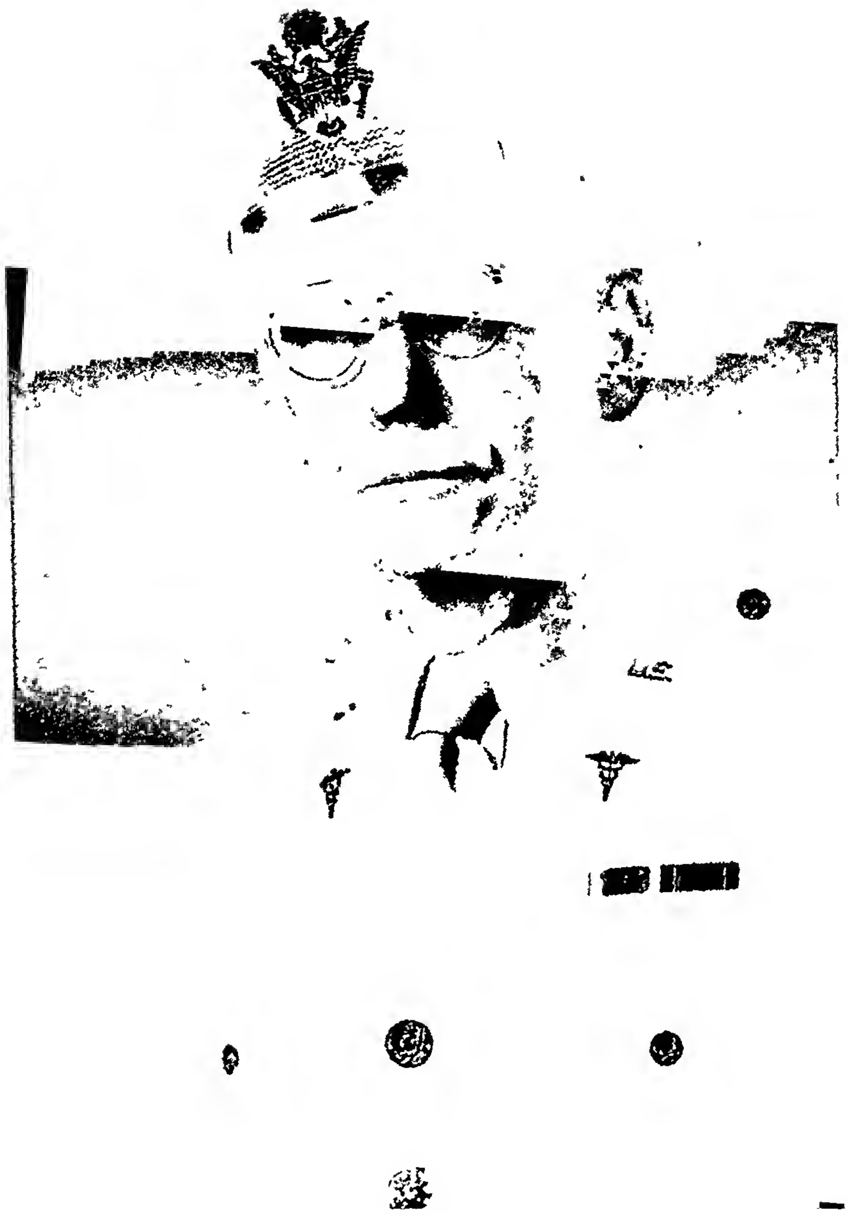
helping ex-service radiologists to obtain the further education and training that so many of them will want as a preliminary to their certification by the American Board of Radiology. From a sentimental standpoint it would seem that the Board might well waive the usual requirements and freely grant its certificate to any candidate, regardless of his qualifications, who has served his country in time of war. That, however, would be directly contrary to the interests of the specialty, of the profession and public it serves, and of the candidate himself. It would be a fine gesture of fully deserved appreciation, but it would also be a step backward, a compromise of integrity and an imposition on the American people; even the recipient of the cheapened certificate would have little esteem for it. As Secretary of the American Board of Radiology I can assert confidently that unless and until membership on its Board of Trustees is radically changed, it will not lower its standards of competence and no candidate will receive a certificate unless he shows by examination that he is fully qualified to receive it. On the other hand, the Board will not deny its diploma to any candidate having served in the armed forces who proves his competence, even though his preparation may have been unconventional or irregular in minor particulars. In September, 1941, the Board adopted a rule that after January 1, 1945, every applicant for certification must have had at least three years' instruction in radiology in a recognized and approved institution. In simple fairness to the ex-service man, this rule will have to be so modified as to give him at least partial credit for time spent in military service because during that period he has been deprived of any opportunity for formalized graduate training and because his military experience has been as valuable in certain fields as institutional instruction would have been. It is improbable that any further concession from the Board can be expected.

At all events, it is apparent that a large proportion of these ex-service men will ask for additional long or short terms of systematic instruction in recognized teaching centers in order to round out their training, and it is going to be difficult to supply courses for all who will want them. Before the war the radiologic departments of hospitals and graduate schools were taxed to capacity. After the war, with ex-service men added to other candidates it will be impossible under present conditions to accept all applicants. Hence it has been suggested that ex-service men be sent in squads to the teaching centers for a period of observation after which the most promising students would be chosen to complete the course. Personally, I believe that most of the teaching institutions could double their capacity during the postwar emergency by reorganizing and streamlining their courses in radiology, by making use of tutors, by exchanging lecturers and by offering intensive short courses like those given by the Army. In addition, the refresher courses given by these two great radiologic organizations might well be lengthened and broadened by home study courses, and independent radiologists not affiliated with schools might combine to offer similar courses in various localities. By these or other measures I believe that the demand for instruction can be satisfied, but considerable effort, coordinated planning and personal sacrifice will be required.

By way of conclusion, it may be pertinent at this time to speculate on the probable influence of demobilized radiologists on the general progress of radiology. For twenty years progress in this specialty has taken the form chiefly of a slow peripheral extension and a more homogeneous dissemination of knowledge related to this science, with few if any striking new discoveries. Indeed, the specialty has threatened to become static, for we, its practitioners, in our zeal to codify and standardize it have perhaps been too conservative, too ready to accept the limitations prescribed by so-called common sense and too

little inclined to use our imaginations. But the young Americans we have been talking about have no such inhibitions. They will come home with scant respect for fixed ideas, taboos and conventional grooves of thought. They will question orthodox beliefs that the opacification of tissues for roentgenologic examination has practically reached its limits, that roentgen diagnosis will never be applicable in fields now considered out of bounds and that irradiation will always be futile in the treatment of certain diseases. And with their abounding energy and daring naiveté they will begin doing impossible deeds. Then we older radiologists shall cease to wonder how we can help them and begin to wonder at what they are doing to help us and our profession.

COLONEL B. R. KIRKLIN
Medical Corps, Army of the United States



Holmes I. Mettel, Baltimore, Maryland

HOWARD ELMER ASHBURY
1880–1945

DR. HOWARD ELMER ASHBURY of Baltimore, Maryland, died on February 20, 1945, of coronary occlusion. Dr. Ashbury was born in Baltimore, April 26, 1880. He received his education in the public schools of Baltimore and graduated from the University of Maryland College of Pharmacy in 1899, and from the University of Maryland School of Medicine in 1903. In 1904 he attended the Post Graduate School of Medicine at the University of Pennsylvania. Dr. Ashbury's early training was

along the lines of orthopedic surgery, but he very soon became interested in roentgenology and, through his friendships with Drs. Caldwell, Gray, Groover, Cole, Brown and others, he obtained a knowledge of roentgenology which served him in good stead throughout his career. Dr. Ashbury was Attending Surgeon at the Hospital for Crippled and Deformed Children from 1904 to 1909; Assistant in Orthopedic Surgery at the Johns Hopkins Hospital from 1910 to 1916; Roentgenologist at St. Joseph's Hospital from 1904 to 1936; Roentgenologist at the Hebrew Hospital from 1910 to 1921; Associate Roentgenologist at the University of Maryland from 1923 to 1927.

His military connections were as follows: Consulting Roentgenologist, U. S. Veterans Administration from 1921 to 1934; Instructor in the Military School of Roentgenology, Cornell University, N. Y., 1917; Professor of Roentgenology United States Army Medical School, Washington, D. C., from 1917 to 1919; Lieutenant Colonel M.C., A.U.S., June, 1941 to February, 1944. He retired from the Army in May, 1944.

Dr. Ashbury was a Deacon of the Presbyterian Church; a Master Mason; a member of the Arts and Letters Club; Society of Colonial Wars; and Sons of the American Revolution. He was a diplomate of the American Board of Radiology; member of American Roentgen Ray Society, American College of Radiology, American Medical Association, Baltimore City Medical Society, Medical and Chirurgical Faculty of Maryland, and a former member of the College of Surgery. In 1910 Dr. Ashbury presented a paper before the American Roentgen Ray Society on the "X-ray Findings in Gastric and Duodenal Ulcers," in which he described flecks in ulcer craters. This was severely criticized at the time, but his findings were later confirmed and have since been considered an important roentgen sign in the diagnosis of gastric and duodenal lesions.

Dr. Ashbury was married to Miss Ellen Hicks of Philadelphia on January 9, 1904. They have two children, Dr. Howard Hicks Ashbury who has taken over his father's practice, and Helen Bartlett Ashbury. Both reside in Baltimore.

Dr. Ashbury was a man of high ideals, thorough and painstaking in his work, and he will be long remembered by his many friends and colleagues.

HENRY J. WALTON

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. H. Dabney Kerr, University Hospital, Iowa City, Iowa. Annual meeting: 1945, canceled.

American College of Radiology
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago.

Section on Radiology, American Medical Association
Secretary, Dr. U. V. Portmann, Cleveland Clinic, Cleveland, Ohio. Annual meeting: 1945, canceled.

Arkansas Radiological Society
Secretary, Dr. J. S. Wilson, Mack Wilson Hospital, Monticello, Ark. Meets every three months and also at time and place of State Medical Association.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: 1945, to be announced.

Radiological Section, Baltimore Medical Society
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

Section on Radiology, California Medical Association
Secretary, Dr. Gordon G. King, 3700 California St., San Francisco 18, Calif.

Radiological Section, Connecticut Medical Society
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets bi-monthly on second Thursday, at place selected by Secretary. Annual meeting in May.

Section on Radiology, Illinois State Medical Society
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

Radiological Section, Los Angeles County Medical Association
Secretary, Dr. Roy W. Johnson, 1407 S. Hope St., Los Angeles, Calif. Meets on second Wednesday of each month at the County Society Building.

Radiological Section, Southern Medical Association
Secretary, Dr. Roy G. Giles, Temple, Texas.

Brooklyn Roentgen Ray Society
Secretary, Dr. Leo Harrington, 880 Ocean Ave., Brooklyn, N.Y. Meets monthly on fourth Tuesday, October to April.

Buffalo Radiological Society
Secretary, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months.

Chicago Roentgen Society
Secretary, Dr. F. H. Squire, 1754 W. Congress St., Chicago 12, Ill. Meets second Thursday of each month October to April inclusive at the Palmer House.

Cincinnati Radiological Society
Secretary, Dr. Samuel Brown, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

Cleveland Radiological Society
Secretary, Dr. D. D. Brannan, 11311 Shaker Blvd., Cleveland 4, Ohio. Meets at 6:30 P.M. at Allerton Hotel on fourth Monday each month, October to April, inclusive.

Dallas-Fort Worth Roentgen Study Club
Secretary, Dr. X. R. Hyde, Medical Arts Bldg., Fort Worth, Texas. Meetings held in Dallas on odd months and in Fort Worth on even months, on third Monday, at 7:30 P.M.

Denver Radiological Club
Secretary, Dr. A. Page Jackson, Jr., 1612 Tremont Place, Denver, Colo. Meets third Friday of each month at Denver Athletic Club.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

Florida Radiological Society
Acting Secretary, Dr. Walter A. Weed, 204 Exchange Bldg., Orlando, Fla. Meetings in May and November.

Georgia Radiological Society
Secretary, Dr. James J. Clark, 478 Peachtree St., Atlanta, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

Radiological Society of Kansas City
Secretary, Dr. Arthur B. Smith, 800 Argyle Bldg., Kansas City, Mo. Meets third Thursday of each month.

Illinois Radiological Society
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meets three times a year.

Indiana Roentgen Society
Secretary, Dr. H. C. Ochsner, Methodist Hospital, Indianapolis. Meets annually second Sunday in May.

Iowa X-Ray Club
Secretary, Dr. Arthur W. Erskine, 326 Higley Bldg., Cedar Rapids, Iowa. Luncheon and business meeting during annual session of Iowa State Medical Society. Special meetings by announcement.

Kentucky Radiological Society
Secretary, Dr. W. C. Martin, 321 W. Broadway, Louisville. Meets annually in Louisville on first Saturday in Apr.

Long Island Radiological Society
Secretary, Dr. Marcus Wiener, 1430-48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:30 P.M.

Louisiana Radiological Society
Secretary, Dr. J. R. Anderson, 1130 Louisiana Ave., Shreveport. Meets annually during Louisiana State Medical Society Meeting.

Michigan Association of Roentgenologists
Secretary, Dr. E. M. Shebesta, 1429 David Whitney Bldg., Detroit. Three meetings a year, Fall, Winter, Spring.

Milwaukee Roentgen Ray Society
Secretary, Dr. C. A. H. Fortier, 231 W. Wisconsin Ave., Milwaukee, Wis. Meets monthly on second Monday at University Club.

Minnesota Radiological Society
Secretary, Dr. Annette T. Stenstrom, 1218 Medical Arts Bldg., Minneapolis, Minn. One meeting a year at time of Minnesota State Medical Association.

Nebraska Radiological Society
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month, at 6 P.M. at either Omaha or Lincoln.

New England Roentgen Ray Society
Secretary, Dr. George Levene, Massachusetts Memorial Hospitals, Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

New Hampshire Roentgen Ray Society
Secretary, Dr. Richard C. Batt, Berlin, N. H. Four meetings a year.

Radiological Society of New Jersey
Secretary, Dr. H. R. Brindle, 501 Grand Ave., Asbury Pk. Meets annually at time and place of State Medical Society. Mid-year meetings at place chosen by president.

New York Roentgen Society
Secretary, Dr. Ramsay Spillman, 115 East 61st St., New York City. Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

North Carolina Roentgen Ray Society
Secretary, Dr. Major Fleming, Rocky Mount, N. C. An-

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

nual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

North Dakota Radiological Society
Secretary, Dr. L. A. Nash, St. John's Hospital, Fargo. Meetings held by announcement.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

Ohio Radiological Society
Secretary, Dr. Henry Snow, 1061 Reibold Bldg., Dayton, Ohio. Meets during annual meeting of Ohio State Medical Association.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport.

Philadelphia Roentgen Ray Society
Secretary, Dr. C. L. Stewart, Jefferson Hospital, Meetings first Thursday of each month, October to May, at at 8:00 p.m., in Thomson Hall, College of Physicians, 21 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. L. M. J. Freedman, 4800 Friendship Ave. Meets 6:30 p.m. at The Ruskin on second Wednesday, each month, October to May inclusive.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Murray P. George, Strong Memorial Hospital. Meets monthly on third Monday from October to May, inclusive, 8 p.m. at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary Dr. A.M. Popma, 220 N. First St., Boise, Idaho.

St. Louis Society of Radiologists
Secretary, Dr. Edwin C. Ernst, Beaumont Medical Building, St. Louis, Mo. Meets fourth Wednesday of each month, except June, July, August, and September, at a place designated by the president.

San Diego Roentgen Society
Secretary, Dr. Henry L. Jaffe, Naval Hospital, Balboa Park, San Diego, Calif. Meets monthly on first Wednesday at dinner.

San Francisco Radiological Society
Secretary, Dr Carlton L. Ould, University of California Hospital, San Francisco 22. Meets monthly on the third Thursday at 7:45 p.m., first six months of the year at Lane Hall, Stanford University Hospital, and second six months at Toland Hall, University of California Hospital.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 p.m., September to May inclusive.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, 707 Walnut St., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. Asa E. Seeds, Baylor Hospital, Dallas, Texas. Next annual meeting, Temple, Texas, Jan. 17, 1945.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 p.m. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 p.m., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. E. L. Flanagan, 116 E. Franklin St., Richmond, Va. Meets annually in October.

Washington State Radiological Society
Secretary. Dr. Thomas Carlile, 1115 Terry St., Seattle. Meets fourth Monday each month, October through May, College Club, Seattle.

X-ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly, third Thursday evening.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Medical Members' meeting held monthly on third Friday at 2:30 p.m. and Ordinary Meeting at same time on following Saturday, October to May, 32 Welbeck St., London, W.1.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month at 4:45 p.m. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. J. W. McKay, 1620 Cedar Ave., Montreal, P. Q.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

South America

Sociedad Argentina de Radiologia
Secretary, Dr. Guido Gotta, Buenos Aires, Argentina. Meetings are held monthly.

Sociedad Peruana de Radiologia
Secretary, Dr. Victor Giannoni, Apartado, 2306, Lima, Peru. Meetings held monthly except during January, February and March, at the Asociación Médica Peruana "Daniel A. Carrión, Villalta, 218, Lima.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse Biel. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad: USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 p.m.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

NOTICE TO DIPLOMATES OF AND CANDIDATES FOR AMERICAN BOARD OF RADIOLOGY

In order to facilitate mailing out notices, it is requested that all diplomates of The American Board of Radiology and candidates for certificates, who have been in the Armed Services or for any other reason have changed their addresses in the past two years, notify the undersigned immediately of their present address or an address at which mail will always reach the individual.

B. R. Kirklin, M.D.
Mayo Clinic, Rochester, Minn.

NORTH CAROLINA RADIOLOGICAL SOCIETY

The Fall Meeting of the North Carolina Radiological Society will be held on October 5 and 6, 1945, at Watts Hospital, Durham, North Carolina. The following program will be presented on Friday, October 5:

Morning Session

Report on Industrial Commission. J. P. Rousseau, M.D., Winston-Salem, N. C.
Case Report. C. L. Gray, M.D., High Point, N. C.
Case Report. James E. Hemphill, M.D., Charlotte, N. C.
Effects of Roentgen Therapy in Experimental Virus Pneumonia. George Baylin, M.D., Durham, N. C.
Experiences in the Army of the United States. G. B. Murphy, M.D., Asheville, N. C.
Boeck's Sarcoid. Paul P. McCain, M.D., Sanatorium, N. C.
Cutaneous Manifestations of Sarcoid. J. Lamar Callaway, M.D., Durham, N. C.
Bone Lesions in Sarcoid. Robert J. Reeves, M.D., Durham, N. C.

Afternoon Session

Diagnosis of Bone Lesions in Childhood. Vincent W. Archer, M.D., Charlottesville, Va.
Treatment of Carcinomas of the Larynx. Hugh F. Hare, M.D., Boston, Mass.

Saturday afternoon, October 6, is to be given over to attendance at the Duke-Navy Football Game at Duke University Stadium, Durham, N. C.

PROFESSOR ANGEL H. ROFFO EXCEPTED FROM RETIREMENT

Decree of the Minister of Justice and Public Education, General Amaro Avalos, excepting Professor Angel H. Roffo from complying with the resolution passed by the General Assembly of Ministers on September 19, 1944.

Whereas:

As it is stated by the National University of Buenos Aires, Dr. Angel H. Roffo, Professor of Cancerology and Director of the Institute of Experimental Medicine, in his uninterrupted scientific work during more than thirty years and in his exclusive dedication to cancer research and treatment, has raised the Institute to an unquestioned scientific degree which, together with his constant preoccupation in those social problems that arise from this terrible scourge, make it indispensable that he remain in charge of the chair and of the Direction of the Institute mentioned:

The Ministry of Justice and Public Education resolves:

To except Dr. Angel H. Roffo, Professor of Cancerology and Director of the Institute of Experimental Medicine, dependent of the National University of Buenos Aires, from complying with the decree given by the Assembly of Ministers on September 19, 1944.

Amaro Avalos
Minister of Justice and Public Education

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, M.D., B.S., M.A., 103 Rutledge Ave. Charleston, S. C.

BODY SECTION ROENTGENOGRAPHY AT AN ARMY STATION HOSPITAL

By CAPTAIN ELI STARR
Medical Corps, Army of the United States

At the Department of Roentgenology of this Station Hospital many occasions arose wherein there was need for body section roentgenography. The table of basic allowances of the United States Army limits roentgen equipment at a station hospital to the conventional type. To the best of my knowledge, apparatus for body section roentgenography is available at few Army general hospitals. With this in mind, a simple method of adapting conventional apparatus for body section roentgenography at Army hospitals was sought. Simplicity and economy were dominant during this investigation. Also the quick and easy conversion of the equipment from conventional roentgenography to body section roentgenography, and then back to conventional roentgenography, was stressed.

In the interest of economy, materials on hand and the help of patients on a reconditioning program at the occupational therapy shop were solicited. Actually very little material and labor were found to be necessary. The sum total of the materials consisted of three wood blocks, a wood slat 45 inches long by 1 inch square, several screws, nails, and 2 large "C" clamps. By the sites of attachment of these blocks, they have been designated as follows:

1. Table block (Fig. 1). This consists of 18 inches of a 2 by 4 inch rafter with set-offs at both ends. Through the center of the block are several drill holes. Two "C" clamps fasten this block to the center of the roentgen table.

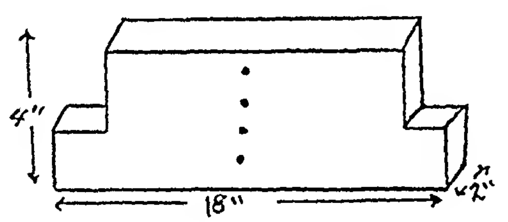


Fig. 1. Table block.

2. Tube clock (Fig. 2). The tube block consists of 10 inches of a 2 by 4 inch rafter grooved at both ends to fit between the horizontal metal arms which support the roentgen tube. Through its center is a 1 inch square slot to receive the wooden slat (see below). This block was designed for the 200 ma. Picker unit (PX-1B).

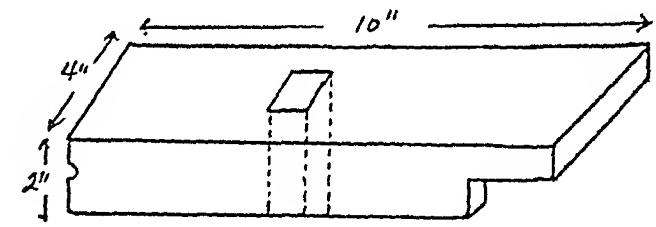


Fig. 2. Tube Block.

3. Film tray block (Fig. 3). This block

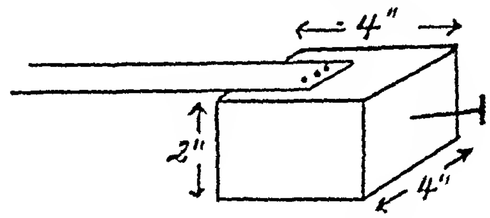


Fig. 3. Film tray block.

measures 4 inches of a 2 by 4 inch rafter. It is screwed to the centering arm of the film tray of the Potter-Bucky grid on the

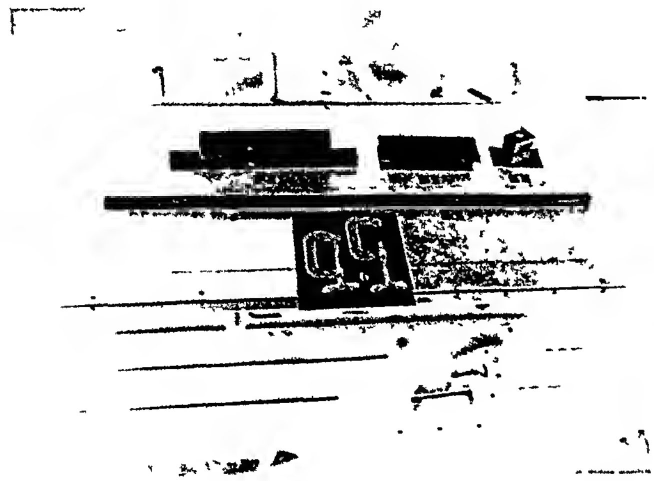


Fig. 4. This shows the components of the unit. *2*, table block; *3*, tube block; *4*, film tray block; *5*, 45 in. slat; *6*, two "C" clamps.

200 ma. Picker roentgenographic roentgenoscopic unit (PX-1B). At the free end of the block a bolt protrudes to receive the lower end of the slat.

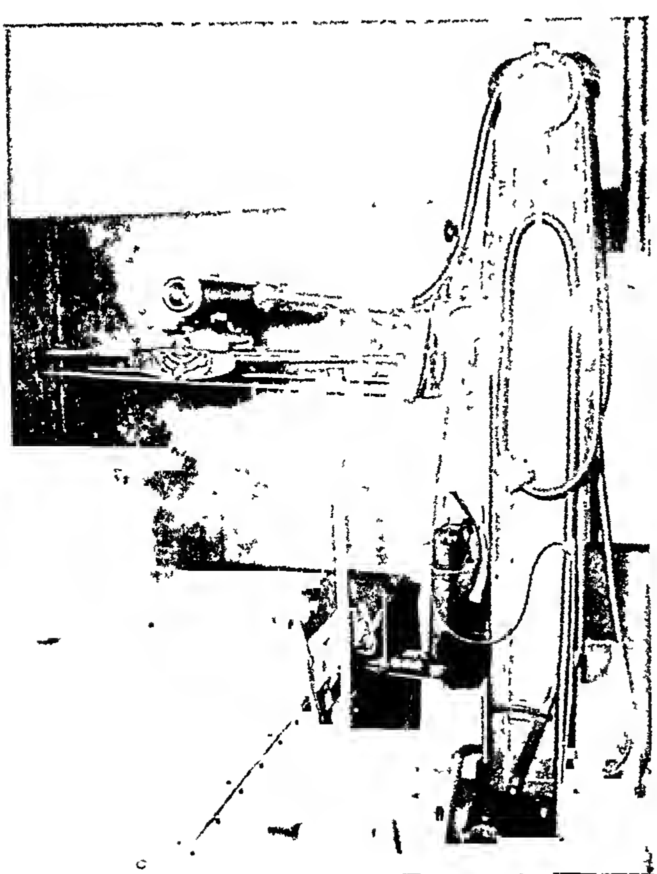


Fig. 5. The unit is shown assembled and ready for use.

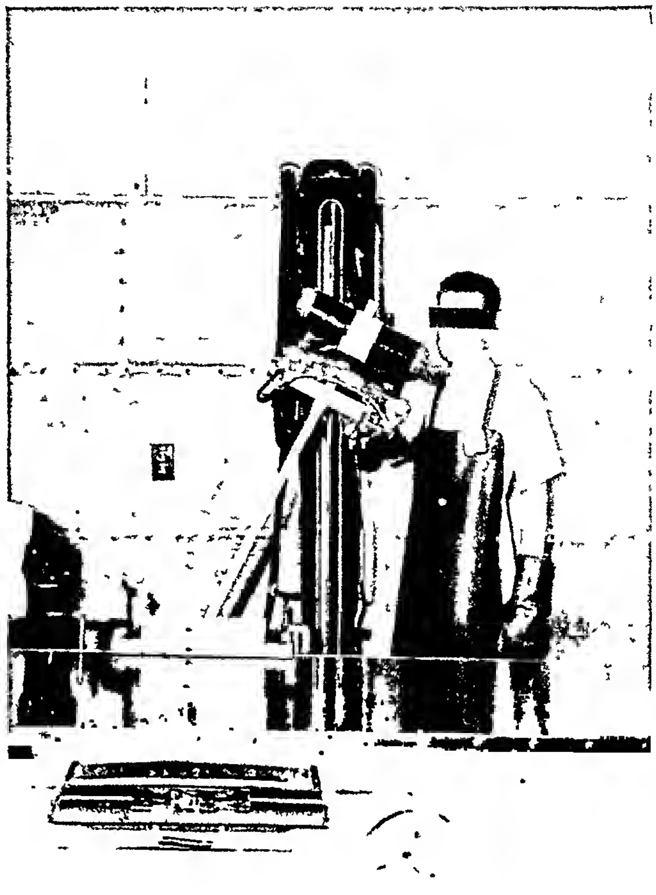


Fig. 6. The technician is shown ready to activate the motion of tube prior to an exposure.

The slat is 45 inches long. It has a 3 inch long slot at its lower end to receive the bolt of the film tray block. Its upper end fits snugly into the tube block. About 6 inches from the lower end are several drill holes. These are brought in alignment with the drill holes of the table block by a long sturdy nail.

When set in motion, this apparatus will allow simultaneous longitudinal movement of the roentgen tube and film in opposite directions. The tube will also tilt as it travels along the table, so that the central ray is always directed over the part to be examined. The fixed axis (point of oscillation) about which the slat revolves is in the table block and is adjustable to the desired focal plane level of the patient by selection of the drill-hole which lies in that focal plane level. The fixed axis always lies in the axis of the focal plane level being examined.

No major technical difficulties have been

[illegible]ed. Technical factors as used for [illegible] roentgenography are quite [illegible]. There have been few exceptions [illegible] the exposure times are varied. The [illegible]-Bucky diaphragm and cone are em-

[illegible] upper half of the right [illegible]

[illegible] of the exposure. A 36 inch [illegible] desirable since [illegible] for tube tracking.

[illegible] continuous [illegible] tube and film. [illegible]

[illegible]

lar. Motion was begun and the exposure made. Roentgenograms produced in this manner are of good diagnostic quality.

The following case is included to illustrate the efficacy of this apparatus.

The patient, a male, aged thirty-four, was admitted to this hospital with a history of blood-streaked sputum, loss of weight, and afternoon elevation of temperature. Sputum examinations were positive for acid-fast bacilli on three occasions. Roentgenographic examination of the chest (Fig. 7) showed dense fibrotic lesions in the lower third of the right upper lobe. These extended from the upper pole of the right lung root to the pleura, which was also thickened. A cavity, about 3 cm. in diameter, was demonstrated above these lesions, however it was not well defined. Body section roentgenograms were made with the apparatus described above. Figure 8 clearly demonstrates the cavity and the involvement of the lower portion of the right upper lobe.

[illegible]

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[illegible]

has been described. The ease of application and removal of this apparatus from the conventional roentgenologic equipment has been stressed. The method of operation and the technical considerations have been included. An illustrative case has been appended.

REFERENCES

1. Andrews, J. R. Planigraphy. 1. Introduction and history. Am. J. Roentgenol. & Rad. Therapy, 1936, *36*, 575–587.
2. Howes, W. E. Sectional roentgenography of larynx. *Radiology*, 1939, *33*, 586–597.
3. Kieffer, J. Laminagraph and its variations; applications and implications of planigraphic principles. Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 497–513.
4. Moore, S. Body section roentgenography with laminagraph. Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 514–522.
5. Wilson, H. M. Exploration of thorax by body-section roentgenography. *Radiology*, 1939, *33*, 598–604.

INDEX TO ABSTRACTS

ROENTGEN DIAGNOSIS

ROENTGEN AND RADIUM THERAPY

ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

GENITOURINARY SYSTEM

Soiland Albert. Peyronie's disease or plastic induration of the penis. *Radiology*, Feb., 1944, *42*, 183–185.

About 650 cases of plastic induration of the penis have been reported. In 1934 the author reported 6 cases in which irradiation had given fairly satisfactory results. In this article he reports 11 further cases and tabulates the results. As this is a keloid type of lesion, surgery is not effective. Most of the patients are over forty years of age and the chief complaints are pain and distortion on erection that may make coitus impossible. Radiation treatment causes loss of libido and though the author has had the best clinical results with a 4gm. radium pack and has carefully screened off the testicles he has not been able to prevent this result. Younger patients should be warned of the possibility.

Practically all types of irradiation have been used and practically all of them have given good results. All cases should be carefully studied and reported in an effort to work out the best dosage and method of irradiation.—*Audrey G. Morgan.*

SKELETAL SYSTEM

Faget, G. H., and Mayoral, A. Bone changes in leprosy; clinical and roentgenologic study of 505 cases. *Radiology*, Jan., 1944, *42*, 1–13.

The bone changes of leprosy are found chiefly in the neural form rather than in the lepromatous or nodular form of the disease. Among the 505 patients observed at the National Leprosarium and discussed in this article, there were bone changes in 64 per cent of the neural cases, in only 5.6 per cent of the lepromatous cases and in 33 per cent of the cases of the mixed type. Both the neural and lepromatous cases generally show changes of the mixed type in the late stages.

The bone changes in the neural type do not result from the presence of the bacilli of leprosy in the bone but are neurogenic and similar to those found in other neurotrophic diseases, such as syringomyelia, tabes dorsalis, and others. They consist of a slow and intensive absorption of bone. This is hastened and increased by trauma, as shown by the fact that it is most pronounced in the hands at the ends of the phalanges, which are most subject to injury, and in the feet at the ball of the foot which bears the weight of the body. The appearance of the bone is like that of a stick of candy that is being sucked away. The differential diagnosis of the bone changes in leprosy must be based on clinical and neurological signs as well as on roentgen findings.

The bone changes found in the lepromatous form of the disease were enlarged nutrient canals, cyst formation, necrosis, osteomyelitis and periostitis. The enlarged nutrient canals are produced by infection of the nutrient vessels with leprosy bacilli. Bone cysts are due to direct action of Hansen bacilli infecting the marrow canal.

Secondary infection generally occurs sooner or later in leprosy cases and confuses the picture. It is hard to differentiate lepromatous osteomyelitis from pyogenic osteomyelitis but in the pyogenic variety there is rapid destruction with no regeneration, while in the leprous form the development is slow and there may be regeneration of bone. Arteriograms were taken in these cases. The changes in the blood supply did not run parallel to the neurotrophic bone absorption in the neural cases but in the lepromatous and mixed cases there were localized arterial defects and decrease in size of the branches of the arteries that suggest that these lesions are vascular in origin. In the upper extremities there may be atrophy and contracture of the muscles or bone absorption but generally the two types of change do not occur together. —*Audrey G. Morgan.*

Cooney, J. P., and Crosby, E. H. Absorptive bone changes in leprosy. *Radiology*, Jan., 1944, *42*, 14–19.

Leprosy affects all the tissues of the body, particularly the skin, nerves, blood vessels and bones, and foci of leprosy have even been found in the lungs. The phalanges of the hands and the metatarsals and tarsals of the feet may be

completely absorbed. The authors made a close study of 15 cases of leprosy in an attempt to explain this complete concentric absorption of bone. They find that there are three factors in bringing about this result, namely disturbances of circulation, anesthesia and pressure. When the circulation to the bone is decreased the bone undergoes consolidation with increased density and osteosclerosis. Leprous degeneration of the peripheral motor and sensory nerve trunks and degeneration of the tracts of Goll and Burdach in the spinal cord bring about the anesthesias of leprosy and the neurocirculatory disturbances. Improvement in the local leprous lesions in the feet has been demonstrated after novocain nerve block. Pressure which is the third factor in bone absorption, does not cause pain because of the anesthesia. Pressure is from local lesions in the soft tissues of the hands and feet and from use, as shown by the fact that the destruction is greatest in the phalanges of the hands which are most subject to use and therefore to injury, and in the arches of the feet which are subject to weight bearing.

These three factors of circulatory disturbance, anesthesia and pressure account for all the bone changes in leprosy.—*Audrey G. Morgan.*

Wolff, Ernest, and Nolan, Lewis E. Multiple myeloma first discovered in the mandible. *Radiology*, Jan., 1944, *42*, 76–78.

A case of myeloma first discovered in the mandible and apparently originating there is described. No such case has been described before. These tumors are usually present in more than one bone at the time of discovery and myeloma has not infrequently been found microscopically in bones that appeared to be normal on roentgen examination.

The patient was a colored woman forty-four years of age who complained of pain and swelling in the left side of the lower jaw which had persisted for eight weeks. Roentgen examination of the jaw showed a large, sharply defined, circumscribed area of decreased density involving the greater part of the body of the left mandible, extending from the symphysis to the angle, with only a thin shell of bone remaining at the margin of the tumor. There was no evidence of new bone formation. The bones of the limbs and trunk were normal but roentgen examination of the skull showed minute, punched-out areas in both parietal bones. Microscopic examination of a biopsy specimen from the jaw showed myeloma of the plasma cell type.

Roentgen treatment was given and after 1,500 r had been administered the pain and swelling subsided. The patient has been under observation for eighteen months and there has been no recurrence, but roentgen examination shows a gradual increase in the size of the punched-out areas of rarefaction in the parietal bones.

Biopsy examinations should be made in all noninflammatory lesions of the mouth and jaws. —*Audrey G. Morgan.*

Harmon, Paul H., and Adams, Carroll O. Pyogenic coxitis I. End-results and considerations of diagnosis and treatment. *Surg., Gynec. & Obst.*, April, 1944, *78*, 371–390.

This paper is based on a study of 147 hip joints in 132 patients.

Etiology and Incidence.

1. Infection of the hip and surrounding structures in this series of cases occurred through the blood stream. In 69 hips, data for which were obtainable, the origin of bacteria was from the upper respiratory tract (including the ear) or from the skin.
2. The causative organism per se does not condition the amount of bone destruction. Extensive osteomyelitis with gross bone loss may result from either b-hemolytic streptococcus or from staphylococcus infection but usually the extent of bone involvement is less and primary synovial infection more common when streptococci are the causative organisms.
3. Males are more frequently affected than females.

Diagnosis

1. Symptoms: Pain, muscle spasm about the hip with the femur in a position of flexion and external rotation.
2. Aspiration of the hip joint with or without arthrotomy is the only method of establishing the diagnosis in doubtful cases. Diagnosis by aspiration is often possible many days and weeks before roentgenograms show a bone focus.
3. Roentgenograms: Two general courses of this condition can be described: (1) The increased intracapsular pressure produces dislocation. The loss of articular cartilage can be inferred only when the bony cortex is eroded. The loss of bone and shortening due to it are dependent upon the extent of bone involved by in-

fection and the efficacy of traction employed in treatment. Late shortening may be the result of closure of the upper femoral epiphysis. Unless dislocation is present, the amount of shortening is usually negligible. (2) When joint distention and subsequent dislocation do not occur diffuse narrowing of the joint space which is usually still occupied by some articular cartilage develops. This alteration may be followed by surface erosion of the underlying articular bone cortex. Rapid osseous ankylosis is then the end-result of this type.

Differential Diagnosis

1. Tuberculosis of the hip—destruction is marginal or in the metaphysis and unassociated with sclerosis, "kissing sequestra" may be present, joint space usually preserved longer, tuberculin reactions usually positive.

2. Legg-Calvé-Perthes' disease—widening of femoral neck, flattening of the head with minimal changes in the acetabulum.

3. Slipped femoral epiphysis—coxa vara and external rotation of the distal fragment.

4. Chronic nonspecific arthritis—loss of joint space without deformity followed later by marginal hypertrophic changes and sclerosis in the weight-bearing portions.

5. Osteochondritis dissecans—the point of origin in the articular cortex from which the sequestrum has separated may be identified.

6. Aseptic necrosis of femoral head—usually history of trauma with fracture of neck or dislocation.

7. Old congenital dislocations—typical history of disability beginning the second year of life.

8. Other conditions to be differentiated include osteogenic and chondrosarcoma, metastatic tumors, syphilitic bone involvement, hemophilia, idiopathic subperiosteal changes in the newborn, xanthomatosis, fibrocystic disease, neurofibromatosis with bone involvement, caisson disease, echinococcus cysts, and bone islands.—*Mary Frances Vastine.*

Harmon, Paul H., and Adams, Carroll O. Pyogenic coxitis 2. Indications for surgical treatment in residual and chronic stages and end-results of reconstruction in 53 patients. *Surg., Gynec. & Obst.*, May, 1944, *78*, 497–508.

In the authors' previous communication dealing with end-results from suppuration in the hip joint, the cases were found to fall naturally into three groups: (1) from zero to three years of age, inclusive; (2) from four to twelve years of age; and (3) an "adult" group thirteen years of age and over. In the first two groups, especially in the second group which included the bulk of the cases, a movable and painless hip often resulted and was a desirable end-result, even though a variable amount of bone of the femoral neck was lost through suppuration and even though osteoarthritis might supervene three decades later. A stable fused hip, especially if superior displacement and dislocation were prevented by traction, was the usual outcome in adults and in certain cases in the juvenile and adolescent groups. This outcome appears likewise desirable. Indeed, in the older cases, if bony union did not occur with elimination of the joint, pain was the usual outcome.

The authors have found it convenient to retain the classification of cases according to age in considering the indications for, and end-results from, operative treatment of the residual deformities met with in this group of cases.

Analysis of Observations

1. No dogmatic statement can be laid down as to the optimum age at which reconstructive procedures should begin.

2. In the case of long continued discharge from deep sinuses, the measures aimed at closing these are quite effective. These measures include the elimination of sequestra, epithelialized sinuses and chronic osseous abscesses. In a few months after subsidence of the acute phase, measures can be undertaken to eliminate discharge from draining sinuses that promise not to close otherwise.

3. The procedures used in reconstruction of the single hip damaged by suppuration are highly successful in juveniles. In adolescents or young adults these plastic operations, including the acetabular shelf, do not give satisfactory results largely because of subsequent pain.

4. Malposition at the fused hip should not receive surgical attention until after the approximate age of twelve to thirteen years unless the malposition is grossly exaggerated (when it may be necessary to correct it by osteotomy). It must be remembered that osteotomy at the earlier ages is seldom a permanent correction as a portion or all of the deformity will recur and need a later correction. Osteotomy in the presence of a movable hip is not subject to the same rigid age limitations as this is usually done to increase hip stability.

5. In general, surgical stabilization of slightly movable hips and positional correction in those already naturally ankylosed by the acute disease yield better permanent results (in terms of painless extremities serviceable in weight-bearing) than arthroplastic attempts to secure a movable hip. Indeed, a number of hip joint arthroplastic procedures were unsatisfactory when performed upon hips ankylosed as the result of suppurative joint disease. Subsequent collapse of the newly formed femoral head was the chief cause of failure. This complication arose because of the altered vascularity produced by sclerosis of this portion of the bone.

6. For the equalization of leg length, the bone shortening operations yielded uniformly satisfactory results in the writers' hands. The epiphyseal arrest operations that were performed were largely done upon adolescent girls and were performed too late, since at that time it was not fully appreciated that longitudinal growth of the long bones in girls often ceases as early as eleven to thirteen years. The leg shortening operation can be applied in the growing child in the latter half of the growth period provided prolonged previous observation has established the fact that the leg length discrepancy is not a progressive one.

7. The least satisfactory end-results were seen in patients presenting bilateral deformities from acute involvement of both hips. Since these patients were seen before the modern era of arthroplasty, little treatment was attempted in them.—*Mary Frances Vastine.*

W[illegible], I[illegible]. Tabetic arthropathy of the hip. *Radiology*, Jan., 1944, *42*, 79–[illegible].

Roentgenograms are given showing the progress [illegible] of Charcot hip from the early stage when there were no roentgenologically [illegible] changes in the bone up to the [illegible] complete disruption of the architecture of the head and a part of the neck of the femur.

The patient was a white woman, fifty-seven years old, [illegible] to hospital July 13, 193[illegible]. [illegible] she had fallen, [illegible] her [illegible]

[illegible]

and the joint slipped out again. This was repeated several times. She was last seen August 30, 1937, when she showed an eversion deformity with 1½ inches of shortening. The roentgenogram showed complete disruption of the architecture of the head and a part of the neck of the femur. The end of the femur was dislocated upward and made no contact with the acetabulum. She refused further treatment.

This case seems to support the theory that Charcot hip may be caused directly by injury but that the predisposing cause is the loss of protection caused by hypotonicity of the muscles.—*Audrey G. Morgan.*

Hartley, J. Blair. "Exhaustion" fracture of the spine. *Brit. J. Radiol.*, Nov., 1943, *16*, 348–350.

Fatigue or exhaustion fracture is not well known in England. It is more common in Scandinavia, continental Europe and Japan. It generally occurs in weight-bearing bones and is seen in nonweight-bearing ones only when they are subjected to some unusual stress or strain. This was true in the case described here in a healthy boy seventeen years of age, 5 feet 10 inches tall and weighing 10 stone, 2 pounds. He had for some time been driving a heavy coal lorry and carrying the hundred weight sacks on his back to the customers' cellars. He turned his back to the sacks and pulled them up on his back where they rested on the lower cervical and upper dorsal region. In May, 1943, he was admitted to the hospital with a diagnosis of Pott's disease based on a history of pain and tenderness on pressure in the upper dorsal region for some three weeks. At the end of this period he suddenly collapsed with very severe pain in the dorsal region. It was sudden in onset and "tearing" in nature and the patient could not sit up without assistance. On admission to the hospital there was tenderness on pressure in the mid-dorsal region but no evidence of systemic disease. The patient had had the usual diseases of childhood but no illness since the age of fourteen. Roentgenograms showed that the fifth dorsal vertebra was wedge shaped, having collapsed much in the manner of compression fractures except that the outlines were entirely clear and there was no evidence of [illegible] injury. [illegible] was normal and the only abnormal finding was the appearance [illegible] of the upper and lower [illegible]. The [illegible] (Continued)

roentgenograms after a week during which the patient had been in bed showed further collapse of the fifth dorsal body; it also showed that there was no demonstrable change in any of the other vertebrae. A diagnosis of fatigue fracture was therefore made; that is, a fracture in apparently normal bone as a result of overload. The site that has suffered stress continues to deteriorate even after the load is removed.

The patient is now immobilized in a Whitman frame; he is comfortable as long as at rest and in two months' observation has not shown any evidence of systemic disease. A future report will be made on his progress which it is hoped will contribute to a better understanding of fatigue fracture.—*Audrey G. Morgan.*

Galluccio, A. C. Spondylolisthesis; general consideration with emphasis on radiologic aspects. *Radiology*, Feb., 1944, *42*, 143–158.

Spondylolisthesis is a slipping of the fifth lumbar vertebra on the first sacral, usually forward, as a result of a defect in the interarticular part of the neural arch of the vertebra. Prespondylolisthesis is a zone of inadequate ossification in the arch which may later result in slipping. Some authors think the condition is congenital while others think it is caused by trauma. The author is inclined to think it is traumatic, at least that trauma is the exciting cause, though there may be a congenital lesion as a predisposing factor. He discusses 15 cases of prespondylolisthesis and spondylolisthesis discovered in the routine spinal examination of 142 soldiers, an incidence of over 10 per cent, which is very high. This may be due to the fact that soldiers lie in the most frequent age group for this condition and that they are subjected to unusual strain in military life. Over 50 per cent of these cases were prespondylolisthesis and 4 of them were discovered incidentally in abdominal examinations.

The patients may complain of symptoms, such as low back pain, weakness, fatigue or stiffness of the lower back, but roentgen examination is necessary for definite diagnosis. If the lesion is detected early its further progress may be prevented by adequate measures. Therefore a detailed description of the anatomy of the region is given and the article illustrated by many roentgenograms and diagrammatic drawings of the conditions found. The author's routine study of the lumbosacral region includes anteroposterior, direct and accurate lateral and right and left anteroposterior oblique views; also the lumbosacral angle view (45° tilt). He believes the most important views are the anteroposterior, the right and left oblique and the true lateral. Good technique is absolutely necessary. The condition is progressive and a constant search should be made for it in both military and civilian patients. It may be important from a medicolegal as well as a clinical point of view.—*Audrey G. Morgan.*

Obletz, Benjamin E. Fresh fractures of the carpal scaphoid. *Surg., Gynec. & Obst.*, Jan., 1944, *78*, 83–90.

Fractures of the carpal scaphoid occur almost exclusively in vigorous young adult males. This report is based on a study of 45 consecutive carpal scaphoid fractures which occurred in an infantry training camp during an eighteen month period.

Anatomy of the Carpal Scaphoid. This is the largest bone in the proximal row of the wrist. The mid-portion is constricted and is known as the "waist." It is at this point that most of the fractures occur. It has been estimated that a fracture through the waist can interrupt the blood supply to the proximal fragment in between 13 and 33 per cent of the cases.

Mechanism of Fracture. In most instances, the history given is that of a fall to the ground. In attempting to break the fall, the victim lands on his outstretched hand. Usually the heel of the palm is the first to strike the ground. The wrist does not hyperextend. (If it did, the result would probably be a Colles fracture instead of a scaphoid fracture.)

Clinical Symptoms and Signs. There is little or no swelling in the wrist. A tender point is present in the anatomical snuff-box. Pain is elicited on passive motion of the wrist in all planes.

Roentgenology. Roentgenograms of the wrist are taken in four positions on a 10 by 12 film. The usual anteroposterior and lateral views are supplemented by one anteroposterior view in ulnar deviation and a posteroanterior view in 45 degree oblique.

Once the fracture is recognized in the four-view film the repair process can best be studied in the single ulnar deviation view repeated at three to four week intervals. Of the 45 fractures studied, 35 were through the waist of the bone, while 10 were through the proximal pole. There were no fractures of the tubercle found in the series studied.

Fracture Physiology. During the first two weeks, there is an acidity at the site of the fracture which brings about a localized absorption of calcium salts. This causes the fracture line to be wider and more distinct on the roentgenogram taken a few weeks after fracture. The reactionary hyperemia during the first few weeks causes the liberation of minute quantities of histamine and acetylcholine as a result of which the bones undergo decalcification and osteoporosis. If the blood supply is interfered with, the bone does not decalcify but retains its normal radiologic density.

There is a lack of subperiosteal callus formation in the scaphoid so reliance on the healing state must be put on the disappearance of the fracture line. A persisting fracture line beyond ten to twelve weeks is indicative of delayed union.

Types of Scaphoid Fractures. (1) Fractures without interruption of the blood supply to either fragment. (2) Fractures with interruption of the blood supply to the proximal fragment.

Concept of Temporary Avascularity. This concept is demonstrated in the type 2 fracture. Immediately after the fracture is immobilized the healing process begins. Fibrous granulations grow across the fracture site bringing new blood vessels from the distal to the proximal fragment. This process is fairly rapid and within a few weeks the blood supply is more or less completely restored. In this manner necrosis of the proximal fragment is prevented.

Clinical Significance of Temporary Avascularity. Excision should be performed only when there is positive roentgen evidence of nonunion of the fracture and aseptic necrosis of the proximal fragment as seen by creeping substitution with its irregular mottled density and partial collapse.

Treatment. It is imperative that the wrist be immobilized as soon as possible after the fracture. The immobilization must be complete, uninterrupted, and maintained until there is definite roentgen evidence of healing.—*Mary Frances Vastine.*

WILLIAMS, E. ROHAN. Two congenital deformities of the tibia: congenital angulation and congenital pseudarthrosis. *Brit. J. Radiol.* Dec., 1943, *16*, 371–376.

Two congenital abnormalities of the tibia are described: anterior angulation and pseudarthrosis. Four cases are described and roentgenograms of the findings given. Congenital angulation of the tibia is often associated with other bone defects, such as congenital absence of the fibula and congenital dislocation of the hip; this suggests that the condition is brought about by a disturbance of mesenchymal growth due to some inherent defect in the germ plasm. Middleton believes that all such deformities as angulation of the tibia, elevation of the scapula and multiple contractures of the limbs are caused by a failure of growth in length of the myocytes. This theory is discussed in connection with the descriptions of the individual cases.

In congenital pseudarthrosis the primary defect is a failure of local osteogenesis. Frequently, however, the child is born with an angulation of the tibia. A fracture occurs later at the site of the angulation and pseudoarthrosis follows healing. Or it may result from treatment for the angulation. In such cases the pseudarthrosis itself is not really congenital. The fact that a roentgen examination does not show a normal bone structure does not mean that it is necessarily absent. It may be present in the form of cartilage which has not undergone normal ossification.

If a child at birth shows any angulation or other abnormality of the bones of the limbs a roentgen examination should be made within a few days to determine the nature of the abnormality and the child should be placed at once under the care of an orthopedist. The functional outlook in these cases is not good.—*Audrey G. Morgan.*

GENERAL

PATERSON, RALSTON. "A helping hand." *Brit. J. Radiol.*, Nov., 1943, *16*, 351–353.

This is a suggestion for help in reorganizing the disorganized radiological services in the devastated countries of Europe. Much material will have been destroyed and personnel scattered often beyond hope of recall. The governments of the allied countries will attend to the more obvious needs of food, shelter and clothing, but the radiologists themselves will have to attend to the matter of rebuilding radiological teaching and practice. There will be great need for plant and accessories of all types, manpower, education in all its forms and direct help in reorganization.

The author suggests the plan of radiological

units in England "adopting" certain units in the devastated countries, something after the manner in which schools have adopted merchant ships, for example. The adopting unit would assume the task of sending men and material to the adopted one. Birmingham could adopt Brussels, for instance, or Edinburgh, Warsaw. The men sent over to help in teaching and reorganization would remain on the staff and the payroll of their native city, so there would be no question of sacrificing permanent positions for ones that would necessarily be temporary. This scheme should be extended not only to the European countries but to China, where it would be a question not only of reorganization but of building up radiological and medical surfaces from the ground up.

The scheme could be extended by asking American radiologists to join in it, and the author believes that with their usual generous spirit the plan would spread rapidly there. This would establish a good foundation for the creation of a new International Radiological Society.—*Audrey G. Morgan.*

Barclay, A. E. Radiology—empiricism or science? *Brit. J. Radiol.*, Nov., 1943, *16*, 344–347.

The author discusses some of the serious mistakes that have been made in radiology, all based essentially on the fact that roentgen-ray methods were used to demonstrate pathology before the normal findings were thoroughly investigated. He points out these mistakes in radiology not to disparage the great results that have been accomplished in spite of all errors, but to show that the scientific approach to the problems of radiology must always be used. Mere empiricism will not accomplish the desired results, and if the possibilities of disaster were great in the comparatively simple radiology of the beginning period they are infinitely greater now when the field of radiology has widened so greatly. Along with increasing opportunity increasing responsibility has developed.—*Audrey G. Morgan.*

Martin, Hayes, and Morfit, H. Mason. Cervical lymph node metastasis as the first symptom of cancer. *Surg., Gynec. & Obst.*, Feb., 1944, *78*, 133–159.

The purpose of this report is to discuss the phenomenon of cervical lymph node metastasis appearing as the initial symptom of cancer from the standpoints of incidence, site of the silent primary lesion and clinical course, with special reference to differential diagnosis. The data used were obtained from review of about 3,800 consecutive cases observed at the Memorial Hospital from 1933 to 1937.

Incidence of Cervical Metastasis as a First Symptom of Cancer

1. The appearance of a cervical swelling or mass (metastasis) was the first and for a time the only symptom noted by the patient in about 8 per cent of all cases of cancer of the mouth, pharynx, and thyroid.

2. The primary growths, if above the level of the clavicle, are most often found in the tonsil or nasopharynx, followed next in the order of frequency by the tongue, extrinsic larynx, floor of the mouth, palate, and paranasal sinuses.

3. The occurrence of a supraclavicular mass, usually on the left and sometimes referred to as the signal node has long been considered of particular significance as suggesting the presence of a silent primary malignant growth below the level of the clavicle. It appears to the authors that the signal node is sometimes an early but rarely an initial symptom.

Symptoms and Clinical Course of Cancer Appearing First in the Form of Cervical Metastasis.

1. Cervical lymph node metastases may reach a diameter of 7 to 8 cm. or even larger without producing any objective symptoms other than visibility and palpability.

2. Disregarded initial or early symptoms of the primary lesion include slight though persistent deafness or "stuffiness" in one ear, slight soreness of the throat or mild dysphagia.

3. The most frequent initial symptom in nasopharyngeal cancer is cervical metastasis (in over 50 per cent of all cases). The reason that so large a proportion of these silent primary growths are at first missed is that this anatomic site requires special apparatus (headlight, throat mirror, soft palate retractor), and a skill acquired only after considerable experience.

4. In the case of a carcinomatous cervical tumor, the authors consider as inconclusive any single negative examination for a primary lesion in the mouth and pharynx no matter how competent the observer. The survival of the patient for at least five years is the only tenable proof that there is no primary growth elsewhere.

Diagnosis.

1. The clinical picture in cases of initially symptomatic cervical metastasis is typical.

There is slow, gradual, progressive asymmetrical enlargement of one or more nodes without any subjective symptoms. Such nodes should always be considered cancerous until proved otherwise. If a silent primary lesion is not discovered on first examination, it is wise to make an aspiration biopsy of the suspected cervical metastasis.

2. If the pathological report is anaplastic carcinoma, transitional carcinoma or lymphoepithelioma, the primary lesion may be suspected as being in Waldeyer's ring (base of tongue, tonsil, or nasopharynx); if the report is epidermoid or squamous carcinoma, the primary lesion may be somewhere in the mouth or pharynx but usually outside Waldeyer's ring; if the report is adenocarcinoma, the primary tumor is probably in one of the major salivary glands, the thyroid, or in an infraclavicular viscus.

3. The forms of cancer which are commonly believed to occur primarily in cervical lymph nodes are, in order of frequency:

a. Lymphosarcoma. Experience in the head and neck clinic has produced strong evidence that lymphosarcoma above the level of the clavicle usually occurs as a result of a single discrete primary lesion in some portion of Waldeyer's ring.
b. Hodgkin's disease. The chances in an adult of an enlarged cervical node being involved by metastatic cancer are far greater (about 9 to 1) than of its being a primary lymphoma. In general, Hodgkin's lymph nodes are firm and scattered in the neck. The apparent origin of the disease is most often (65 per cent) in the neck.
c. Leukemia. In the early leukemic phases, only a slightly abnormal blood picture may be found and differentiation is then difficult.
d. Primary carcinoma of cervical lymph nodes. It seems to the authors that the evidence for the existence of epithelial rests within lymph nodes giving rise to cancer is rather tenuous.
e. Endothelioma. The records of the past twenty years of the Memorial Hospital contain no instance of endothelioma of cervical lymph nodes.

4. Other conditions to be considered in differential diagnosis include:

a. Thyroid and aberrant thyroid cancer.
b. Branchiogenic carcinoma.
c. Carotid body tumor.
d. Primary tumors of soft parts of the neck (excluding lymph nodes).
e. Acute infection.
f. Tuberculosis.
g. Syphilis.
h. Branchiogenic and thyroglossal cysts.—*Mary Frances Vastine.*

KEPLER, EDWIN J., DOCKERTY, MALCOLM B., and PRIESTLY, JAMES T. Adrenal-like tumor associated with Cushing's syndrome (so-called masculinovoblastoma, luteoma, hypernephroma, adrenal cortical carcinoma of the ovary). *Am. J. Obst. & Gynec.*, Jan., 1944, *47*, 43–62.

It is well known that arrhenoblastomas of the ovary masculinize their hosts. However, it is not generally appreciated that other tumors of the ovary also are capable of producing similar changes in sexual characteristics. Unlike arrhenoblastomas, these tumors are associated with many of the general and metabolic symptoms, such as hypertension, cutaneous striae and diabetes, that characterize Cushing's syndrome, Cushing's disease and tumors of the adrenal cortex. The authors feel that it is wise to speak of these tumors of the ovary as "adrenal-like ovarian tumors." To date, 13 well authenticated cases of such adrenal-like ovarian tumors have been reported in addition to the one which is reported in this article. They are discussed from the following standpoints:

Histogenesis. From the standpoint of pure cytology the origin of these tumors is a histogenic jigsaw puzzle. Histopathologically, these tumors conceivably might arise from one of the following structures: (1) the adult corpus luteum; (2) a pre-existing granulosa-cell tumor; (3) an adrenal cortical ovarian rest, and (4) through excessive development of certain cellular elements (adrenal cortical?) in a teratomatous growth. The origin from adrenal cortical rests seems the most probable. Some of the tumors appear to be cytologically malignant and in one instance death resulted from metastasis.

Clinical Manifestations. These tumors tend to be characterized by pathognomonic changes in the facies and habitus which were described by Cushing. In addition, there is amenorrhea, hirsutism, acne, enlargement of the clitoris and other symptoms usually considered to be indicative of masculinization. Of particular interest is the occurrence of an unusual combination of

symptoms, namely, hypertension, polycythemia and diabetes.

Urinary Hormonal Substances. At present, the tendency is to emphasize the significance of the presence of excessive quantities of 17-ketosteroid material in the urine of adrenal cortical tumors. From the authors' experience with a number of cases of proved adrenal cortical tumor, they do not believe there is reason to believe that the excessive excretion of these compounds is necessarily a concomitant of adrenal cortical tumor. Furthermore, when these compounds are excreted, the values obtained do not by any means parallel the intensity of the clinical picture.—*Mary Frances Vastine.*

Moore, Morris, and Jorstad, Louis H. Histoplasmosis and its importance to otorhinolaryngologists. A review with report of a new case. *Ann. Otol., Rhin. & Laryng.*, Dec., 1943, *52*, 779–815.

The authors review the literature on this disease and report a case of their own in which the clinical impression was carcinoma of the buccal mucosa. They have tabled 22 cases of histoplasmosis collected from the literature in which there was ear, nose and throat involvement.

Etiology. The organism responsible for reticulo-endothelial cystomycosis or histoplasmosis, as first described in tissue by Darling, in 1905, was named *Histoplasma capsulatum* because it appeared very much like a protozoon. The true fungous nature of the organism was not confirmed until the publications of DeMonbreun and of Hansmann and Schenken in 1933. Histoplasma is seen in reticulo-endothelial phagocytes, in monocytes, alveolar cells, epithelial cells as of the buccal mucus, in bone marrow and in the peripheral blood or freely distributed in affected tissue.

Epidemiology and Geographical Distribution. Histoplasmosis is probably not an epidemic disease. It is believed that animals act as carriers of the disease. The portal of entry has been conjectured to include the oral cavity, the respiratory tract, the skin and the ear.

To date, cases have been reported from widely distributed points in the United States, from the Panama Canal Zone, the Philippines, Honduras, Java, Argentina, Brazil, Austria, France, South Africa and Mexico.

As far as can be determined, the incidence in histoplasmosis is not related to sex, color, age or nationality.

Pathology. In general, there has been enlargement of the spleen and liver accompanied in most cases with tubercle-like nodules varying in size and simulating miliary tuberculosis. The superficial and deep lymph nodes have usually been enlarged. Most of the internal organs have been affected either with nodules or ulcers.

Microscopically, necrotic areas are seen. These have a central proliferation with loss of cellular structure. The fungi are present in large numbers within large mononuclear cells of the reticulo-endothelial system.

Clinical Manifestations and Symptomatology. Like other mycotic infections which tend to become systemic and present a granulomatous picture, histoplasmosis can be divided into several distinct types:

1. Cutaneous histoplasmosis. Clinically the lesions may be papules, papillomata, ulcers, suppurative processes with exudate or scaling nodules.
2. Mucocutaneous type. The lesions are found at the mucocutaneous junctions spreading to the adjacent skin or mucous membrane. They are chiefly ulcerative.
3. Otitic type. All the symptoms of otitis media are present in this type. Histoplasmosis of the external auditory canal has been noted.
4. Naso-oral type. The buccal mucosa is most often involved usually showing an ulcerous lesion which tends to spread to the gums, palate, tonsils and fossa and then to the larynx.
5. Systemic histoplasmosis.
6. Pulmonary type. Histoplasmosis of the lungs has occurred in practically all of the cases that have been examined postmortem. It is similar in many respects to miliary tuberculosis.
7. Gastrointestinal type. This is to be differentiated from amebic dysentery and ulcerative colitis.
8. Genitourinary type. Histoplasmosis of the genitourinary tract is not an uncommon finding.
9. Bone and joint type. Key and Large have reported the one case of this type recognized to date.
10. Other types. The organism may cause an endocarditis. Brain involvement has been found in a few cases.

Diagnosis and Differential Diagnosis. In order to establish the diagnosis, the organism must be either demonstrated or cultivated.

The diseases which have been included in the differential diagnosis are: Delhi or Oriental boil, leukemia cutis, dermatitis exfoliativa, cutane-

ous leishmaniasis, blastomycosis, tuberculosis cutis, impetigo, noma, syphilis, otitis media, papillomata, rhinosporidiosis, leishmaniasis of the nose, carcinoma, kala-azar, miliary tuberculosis, Addison's disease, Banti's or Gaucher's disease, aleukemic leukemia, lymphosarcoma, lymphadenoma, aplastic anemia, Hodgkin's disease, pulmonary tuberculosis, pneumonia, ulcerative colitis, tuberculous enteritis, regional ileitis, amebic dysentery, bacillary dysentery, tuberculosis of bone, bacterial endocarditis, blood dyscrasias, undulant fever and malaria.

Prognosis and Treatment. Histoplasmosis is invariably a fatal disease. Treatment has therefore been extremely varied.—*Mary Frances Vastine.*

ROENTGEN AND RADIUM THERAPY

UHLMANN, ERICH M., and GOLDNER, M. G. Use of the basal metabolic rate in the management of radiotherapy for leukemia. *Radiology*, Feb., 1944, *42*, 165–174.

It was found by chance in the examination in 1939 of a leukemia patient who had had previous treatment for lymphatic leukemia that a pathological rise in the rate of basal metabolism took place earlier than any change in the other symptoms of the disease and was also influenced by treatment earlier than the other signs of the disease. It has long been known that the basal metabolic rate is high in the majority of leukemia patients. This is true not only of lymphatic and myelogenous leukemia but also to a certain extent of Hodgkin's disease.

Histories and charts are given of a number of cases in which this finding was confirmed by follow-up. The metabolic rate runs parallel with the number of leukemic cells and is evidently a result of the high oxygen requirement of the leukemic blood cells. This would seem to indicate that the leukemias are a special and peculiar type of neoplasm. No other form of tumor is characterized by increased oxygen requirement.

The basal metabolic rate should therefore be used as the criterion for beginning and terminating treatment. Formerly it was thought advisable to give radiation treatment in leukemia till the number of white cells returned to normal. This often resulted in fatal leukopenia. But by using the basal metabolic rate as the determining factor much lower doses can be given than formerly. With the smaller dosage the patient tolerates the treatment much longer and life is lengthened by this increased term of treatment.

The authors give irradiation over the trunk at a distance of 100 cm. with single doses of 15 to 35 r. The number of treatments varies from two to thirteen and the patients tolerate these treatments very well.—*Audrey G. Morgan.*

TICE, GALEN M., and CURRAN, E. J. Treatment of retinoblastoma; radiation therapy supplementing surgical treatment. *Radiology*, Jan., 1944, *42*, 20–33.

Retinoblastoma is the second in frequency of malignant tumors of the eye. It develops in the ciliary portion or posterior segment of the retina and grows into the eyeball. It has a tendency to extend backward along the optic nerve, which renders surgical treatment difficult. About 90 per cent of the cases occur in children less than four years of age.

The authors discuss 20 cases they have treated, 10 of which were bilateral. They recommend irradiation following enucleation of the affected eye. The diagnosis can usually be made from the clinical picture but calcification occurs in 75 per cent of these tumors and therefore roentgen examination should be made in an attempt to demonstrate the mottled irregular pattern of such calcifications.

They insert monel metal radium needles, four to six, around the nerve stump of the enucleated eye immediately after enucleation. The dose given varied from 400 to 1,000 milligram-hours. A dose as high as 1,350 mg-hr. has been given. Low filtration is used in order to give a relatively intense dose in a comparatively short time and at a short distance. But the caustic dose may injure the remaining eyeball if used there, so roentgen therapy with 200 kv. and heavy filtration is used for the other eye. The beam is directed through three small fields, cross-firing the eyeball. Recurrent tumors are more apt to become infected than primary ones and therefore the authors use radium implants only after the removal of primary tumors, not after recurrent ones. Any of the complications which occur after roentgen therapy, such as keratinization of the conjunctiva and corneal epithelium, glaucoma, cataract and atrophy of the eyeball, may occur after this radium treatment.

The histories of the 20 cases are given. Four of the patients with unilateral tumor and 4 of those with bilateral tumor are still living, a recovery rate of 40 per cent.

In the discussion Dr. Kaplan said that in the irradiation of any lesion about the eye he ap-

plies a few drops of castor oil under the lid, which decreases the damage of the sclera by the irradiation.—*Audrey G. Morgan.*

Cutler, Max. Cancer of the larynx; radiotherapeutic test as an aid in choosing between operation and irradiation. *Arch. Otolaryng.*, Jan., 1944, *39*, 53–58.

The difficulties associated with surgical procedures performed on previously irradiated tissues are well known. Irradiation of the blood vessels and connective tissues injures them and thus impairs the circulation and delays normal healing. These changes may also render the operative area more susceptible to infection. The degree and the duration of this damage of tissues depend on the extent and the type of radiation employed. In the early days of radiotherapy severe damage to normal tissues frequently occurred. Telangiectasis, atrophy and induration of the skin and subcutaneous tissues were common. An important feature of the improvement in radiotherapy has been the better preservation of the tissues constituting the tumor bed. Thus, the ideal form of radiotherapy is specific in the sense that it destroys the neoplasm without causing permanent damage to the connective tissue and blood vessels of the tumor bed. This progress has been accomplished by increasing the voltage of roentgen rays (400 kv.), by increasing the filtration (5 mm. of copper), by using low roentgen intensity (4.2 r to 6.3 r per minute), by using the smallest possible cutaneous fields (25 to 9 sq. cm.) and by using the penetrating gamma ray of radium when this method of treatment is indicated.

In order to gain direct information on this problem in relation to the larynx, the author and his colleagues studied a group of cancers of the larynx treated by the latest methods of roentgen therapy followed by laryngectomy. The lesions had been diagnosed as carcinoma and were selected with great care as being too extensive for laryngofissure but apparently not beyond cure by laryngectomy. Roentgen therapy was used as the initial procedure for one or more of the following reasons: (1) there was partial mobility of the structures leading to the possibility of adequate radiosensitivity for cure by irradiation; (2) the lesion was a small cell plexiform epidermoid carcinoma of the transitional cell type; (3) the patient was of advanced age or in a poor general condition; (4) the patient requested or insisted that radiotherapy be tried as the initial procedure.

Summary. The radiotherapeutic test proved to be of value in testing the relative radiosensitivity of carcinoma of the larynx. The information gained by use of this test is of practical value in helping decide between operation and irradiation under circumstances in which a decision is otherwise difficult. If the lesion shows a favorable response, the second cycle of treatment is administered; otherwise, laryngectomy is performed four to six weeks after the completion of the therapeutic test.

(In the 4 cases on whom treatment data were given, 4,975 to 5,400 r was delivered to one field within an eleven day period.)—*Mary Frances Vastine.*

Rowe, Edward W., and Frazer, Maurice D. Roentgen therapy of Wilms' tumor. *Radiology*, Feb., 1944, *42*, 107–116.

Wilms' tumor is an embryonal mixed tumor of the kidney that usually occurs in children three to five years of age. They do not usually come for treatment until there is a palpable mass in the kidney region. The hematuria and pain seen in kidney tumors in adults are not always present. These tumors should not be palpated more than is necessary as metastases take place through the blood.

The authors describe and illustrate with roentgenograms 4 cases they have treated. They were in children five, eight, three and eight years of age. One case was treated by operation followed by postoperative irradiation; the patient died within five months. The others were given preoperative irradiation followed by operation and postoperative irradiation. They are alive four years, two years and seven months after operation. From a review of the literature and their own cases, the authors conclude that the treatment of choice in these cases is preoperative irradiation, operation and postoperative irradiation. In their preoperative irradiation they give a dose of 3,500 to 4,000 r measured with backscatter through four to six fields, using 200,000 volts, Thoraeus A filtration, 50 cm. distance, 18 ma. and a half-value layer of 2.250 mm. copper.

Close cooperation between urologist and roentgenologist is necessary in order to determine the right time for operation. Nephrectomy should follow preoperative irradiation in four to six weeks and operation should be followed by postoperative irradiation in three to six weeks, or as soon as the condition of the patient permits.—*Audrey G. Morgan.*

ORNDOFF, BENJAMIN H. Castration in malignant and nonmalignant disease. *Radiology*, Feb., 1944, *42*, 159–164.

Sex hormones not only stimulate growth but also stimulate the production of glandular elements in the breast and prostate. The production of sex hormones is reduced or inhibited by castration, either surgical or by means of roentgen rays. In the treatment of carcinoma of the prostate the first effort should be to bring about such decrease or inhibition of the action of the male sex hormone and in cancer of the breast inhibition of the action of the female sex hormone. There is no doubt that the hormone production of pregnancy and lactation stimulates malignant disease of the breast. Treatment in such cases should be first termination of the pregnancy, preferably by irradiation and surgical removal of the products of conception if they are not discharged spontaneously. Preoperative irradiation of the affected breast should be given, followed by removal of the breast and postoperative irradiation of both the affected and nonaffected sides. This will bring about early cessation of menstruation. It is also advisable to continue irradiation of the pelvis at intervals of sixty to ninety days until all the symptoms of the climacterium have stopped, or for at least two years regardless of symptoms. Some androgenic agent, such as testosterone or desoxycorticosterone propionate should be given in daily doses of 10 mg. or more during postoperative irradiation and at intervals thereafter.—*Audrey G. Morgan.*

SCHEFFEY, LEWIS C., THUDIUM, WILLIAM J., and FARELL, DAVID M. Further experience in the management and treatment of carcinoma of the fundus of the uterus, with 5-year end results in 75 patients. *Am. J. Obst. & Gynec.*, Dec., 1943, *46*, 786–802.

The authors include the following points in their summary and conclusions as the result of the study of 127 patients having carcinoma of the fundus. This work is from the Department of Gynecology and the Tumor Clinic, Jefferson Medical College Hospital, Philadelphia.

1. The average age of the postmenopausal group was 58.9 years, and the diagnosis was suspected correctly in 90 per cent of the patients because of the postmenopausal bleeding alone. The postmenopausal group included 78.7 per cent of the patients with carcinoma of the fundus.

2. In the premenopausal group (21.3 per cent) the average age was 46.3 years. In 10 per cent carcinoma was not suspected. Abnormal uterine bleeding was the most significant and reliable finding in 96 per cent of the entire series. It is among the younger women who have not ceased menstruating that irregular bleeding is too often regarded as benign in origin, and ill-advised or inadequate treatment results.

3. The value of diagnostic curettage is apparent for omission of the procedure was especially costly in certain instances. No known ill results followed its use.

4. Fibromyomas were noted in approximately 38 per cent of all patients treated surgically and palpation suggested their presence in a number of irradiated patients. Previous pelvic operative procedures had occurred in nearly 30 per cent of all the patients.

5. Carcinoma was thought to be limited to the uterus in 74 per cent of the patients when they were first seen.

6. It is not a simple matter to establish a decisive gradation of malignancy in every case. Not infrequently the picture is a varied one. It would seem that low-grade lesions respond equally well to irradiation and surgery. However, the survival rate in intermediate and high-grade lesions seems to be materially improved where irradiation has been a factor in the treatment, either singly or in combination with surgery. Prognosis based on the grade of malignancy alone is uncertain; it is only one of the various factors that must be considered.

7. The various methods of treatment used are described in detail with presentation of the relative five year end-results respectively, as follows: (*a*) surgery alone, 18.1 per cent; (*b*) irradiation alone, 40.5 per cent; (*c*) surgery and irradiation, 38.4 per cent. Irrespective of the type of treatment, the five year end-results are 38.6 per cent absolute and 39.1 per cent relative.

8. The authors are convinced that preliminary irradiation with radium, followed by complete operation eight to ten weeks later is the treatment of choice in carcinoma of the fundus. With relation to intrauterine radium dosage, residual carcinoma was absent in 7 of 9 patients in the series who received an intrauterine dosage of 4,000 to 5,000 mg-hr.—*Mary Frances Vastine.*

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THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

Vol. 54 OCTOBER, 1945 No. 4

DIFFERENTIAL DIAGNOSIS OF TUBERCULOSIS IN JOINTS OF THE EXTREMITIES*

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As long ago as 1924, in roentgenological and surgical journals, Phemister[1,2] recorded points which still stand as the principal distinguishing features of tuberculous and non-tuberculous suppurative arthritis. Since it appears that these criteria are not so widely known or so generally employed as their importance warrants, restatement and further illustrations seem indicated.

In his articles Phemister wrote that in pyogenic (non-tuberculous) arthritis, the articular cartilage is killed and broken down first at the points of contact and pressure of opposing articular surfaces; that in these infections proteolytic ferments assist greatly in the rapid removal of the necrotic cartilage. In terms of roentgenology, this means that in pyogenic arthritis there is early narrowing or disappearance of the joint space, and the earliest bone destruction occurs on the opposing, or weight-bearing, portions of the articular surfaces.

In contrast with this, Phemister notes that in tuberculous arthritis the articular cartilage is not killed first, but rather is protected at the points of contact and pressure of opposing articular surfaces; that its earliest destruction is peripheral, along the free surfaces where tuberculous granulations can grow onto and remove it. Proteolytic ferments, present in pyogenic infec-

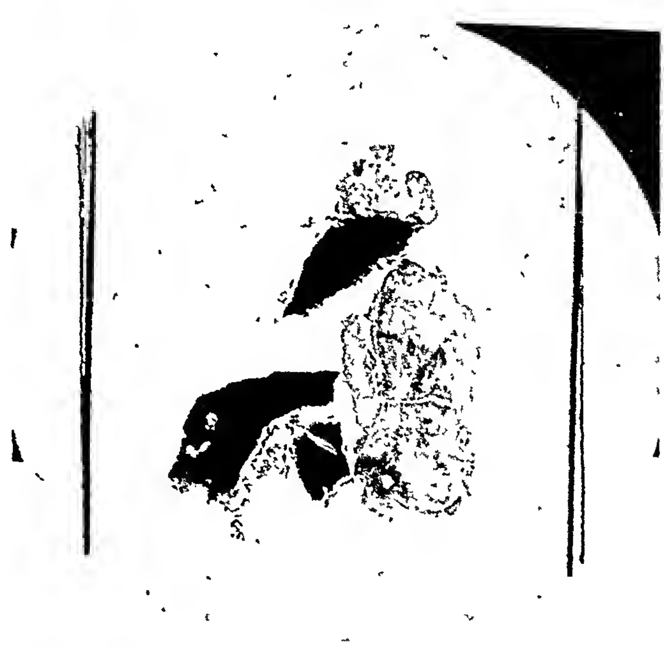

Fig. 1. Tissue excised from a tuberculous joint. The articular cartilage is dead and detached from the bone, and lies unabsorbed in the joint. The pathologic process illustrates how the joint width is maintained by the persistence of the cartilage even though dead. (Courtesy of Dr. Milton Helpern, Director of Laboratories.)

* Presented at the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, Chicago, Ill., Sept. 24–29, 1944.

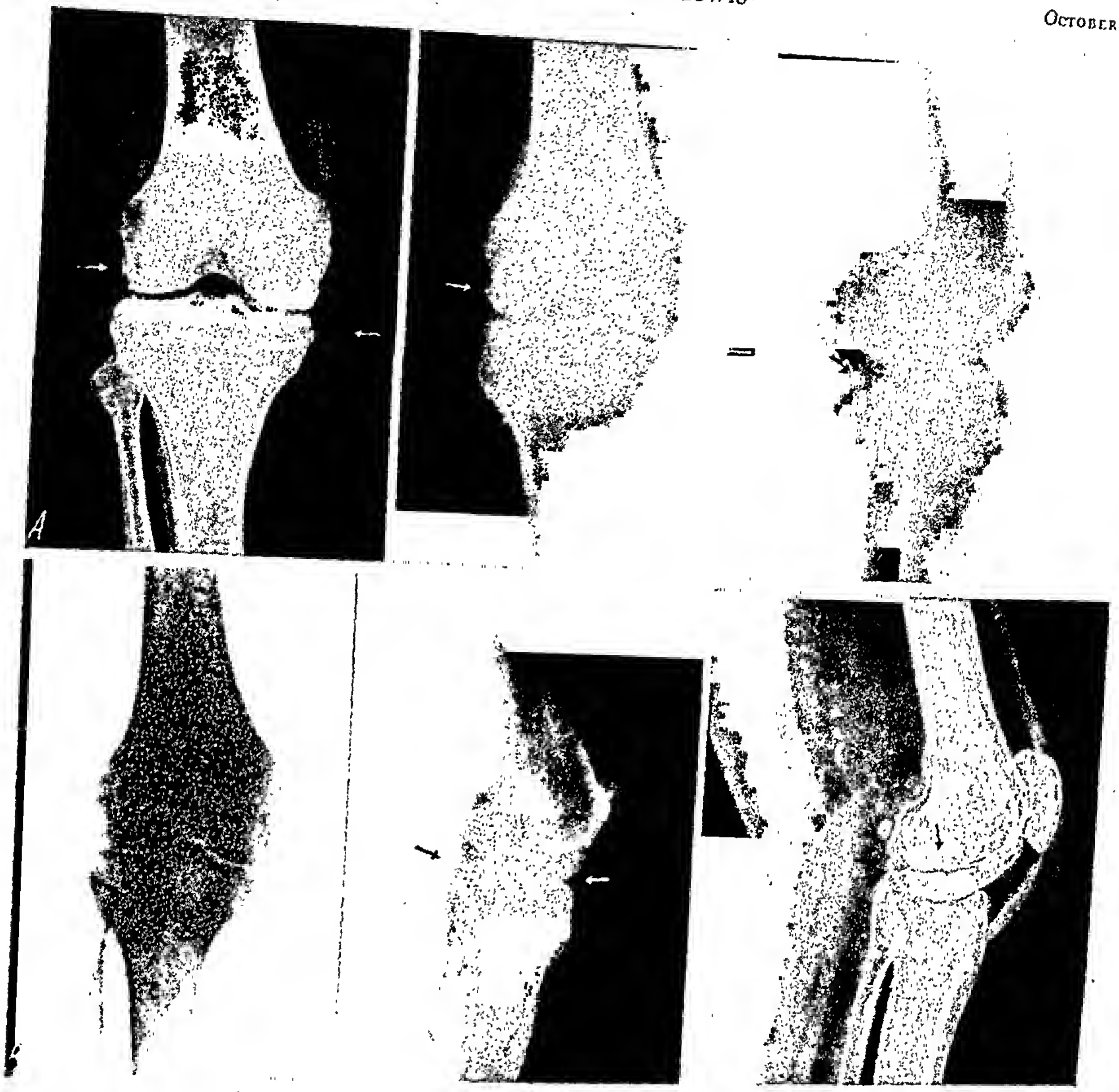

Fig. 2. Characteristic examples of proved tuberculous and non-tuberculous arthritis.

A, tuberculosis: marked synovitis, well preserved joint width, slight bone destruction at the margins of the weight-bearing portions of the articular surfaces. T. McK., male, aged twenty-seven, pain and disability in the right knee of two years' duration. Easily recognized roentgenographically as tuberculosis. Specimen removed at operation reported tuberculosis by the pathologist.

B, non-tuberculosis: marked synovitis, narrowed joint space, slight bony erosion on the weight-bearing portions of the articular surfaces. B. C., female, aged forty-seven, pain and swelling of right knee of ten years' duration. Sent to the hospital as suspicious of tuberculosis. Diagnosed roentgenologically as non-tuberculous arthritis. Report of pathologist on specimen removed at operation: chronic proliferative synovitis.

tions, are absent in tuberculous arthritis, and masses of dead cartilage may persist for months or years, showing few signs of progressive destruction. The first disappearance of the bony cortical shadow (that is, bone destruction) is usually seen peripherally, about the margins of the weight-bearing portions of the articular surfaces, where there has been absorption by the granulations. These observations, in terms of roentgenology, mean that in tuberculous arthritis there is preservation of the joint width for months or years, since the cartilages, though dead, are still present to hold the bones apart; and that the earliest bone destruction is not on the contiguous opposing bony surfaces, but about the margins of the weight-bearing surfaces.

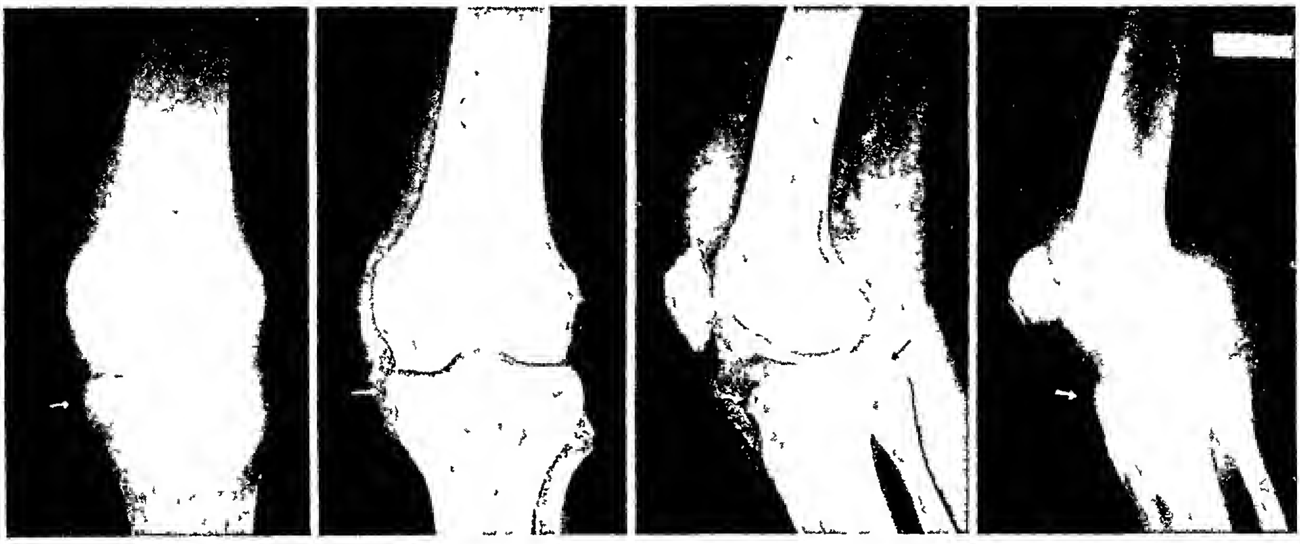

Fig. 3. Proved case, recognizable roentgenographically as early tuberculosis. Roentgen findings: Severe synovitis, joint space well preserved, small areas of bone roughening and deposit anteriorly, posteriorly, and medially at the margins of the upper tibial articular surface. History: R. D., male, aged twenty-one, had spent eight months in a sanatorium because of pulmonary tuberculosis. Four months ago struck his left knee, since when he has had pain and swelling. Roentgen report: strongly suggestive of tuberculosis. Pathologist's report: tuberculous synovitis.

To these primary points of differentiation may be added a few other distinguishing characteristics: (1) in acute suppurative arthritis occurs rapid and severe osteoporosis immediately about the joint, doubtless the result of the acute congestion of the

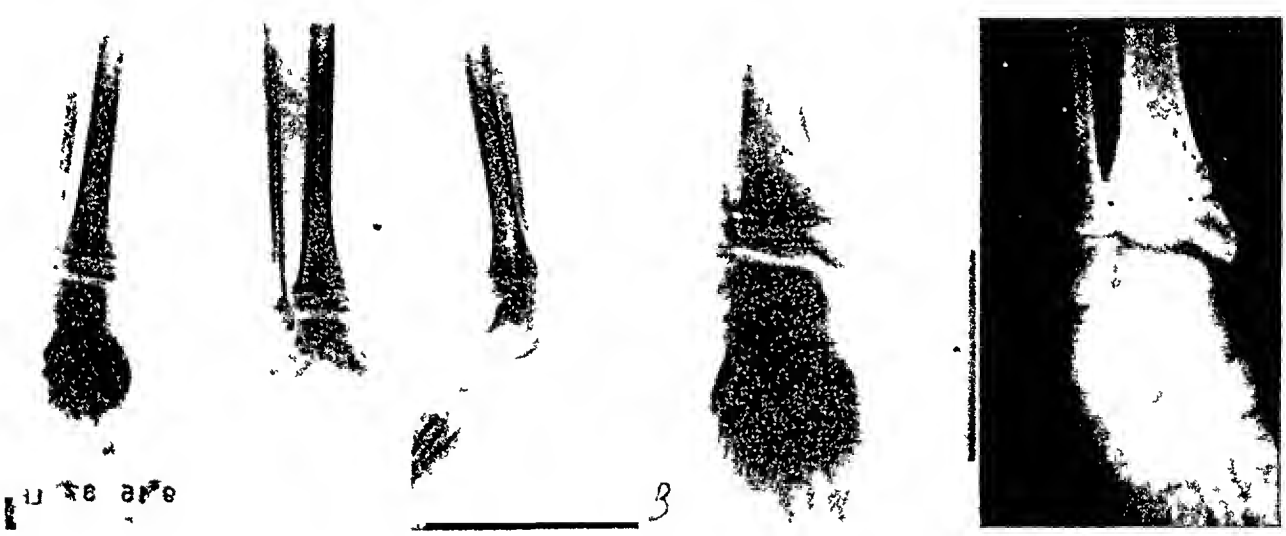

Fig. 4. Proved tuberculosis in a child, showing that the pathological processes and roentgenographic findings are essentially as in adults. History: F. F., female, aged four, had for the past twenty months been under treatment at this hospital for tuberculosis of the ankle joint, with onset of symptoms twenty-one months ago, and with the diagnosis established three months after onset by guinea pig inoculation of fluid aspirated from the ankle joint. Roentgen examination twenty-one months after the onset of symptoms (*A*) showed marked synovitis, no narrowing of the joint space, no evidence of bone destruction. Shortly after this, the patient left the hospital for a six year interval, eventually returning only because of weak feet. At this time she had no complaint with reference to the ankle, and physical examination and roentgenographic examination gave no suggestion of present or recent activity. The disease was either quiescent or cured. Roentgenographically (*B*) the joint width was found normal, there was slight old irregularity of the bones.

Comment. In a case of proved tuberculosis of the ankle joint in a child, followed for two years and then re-examined six years later when the disease was either quiescent or cured, there was never narrowing of the joint space.

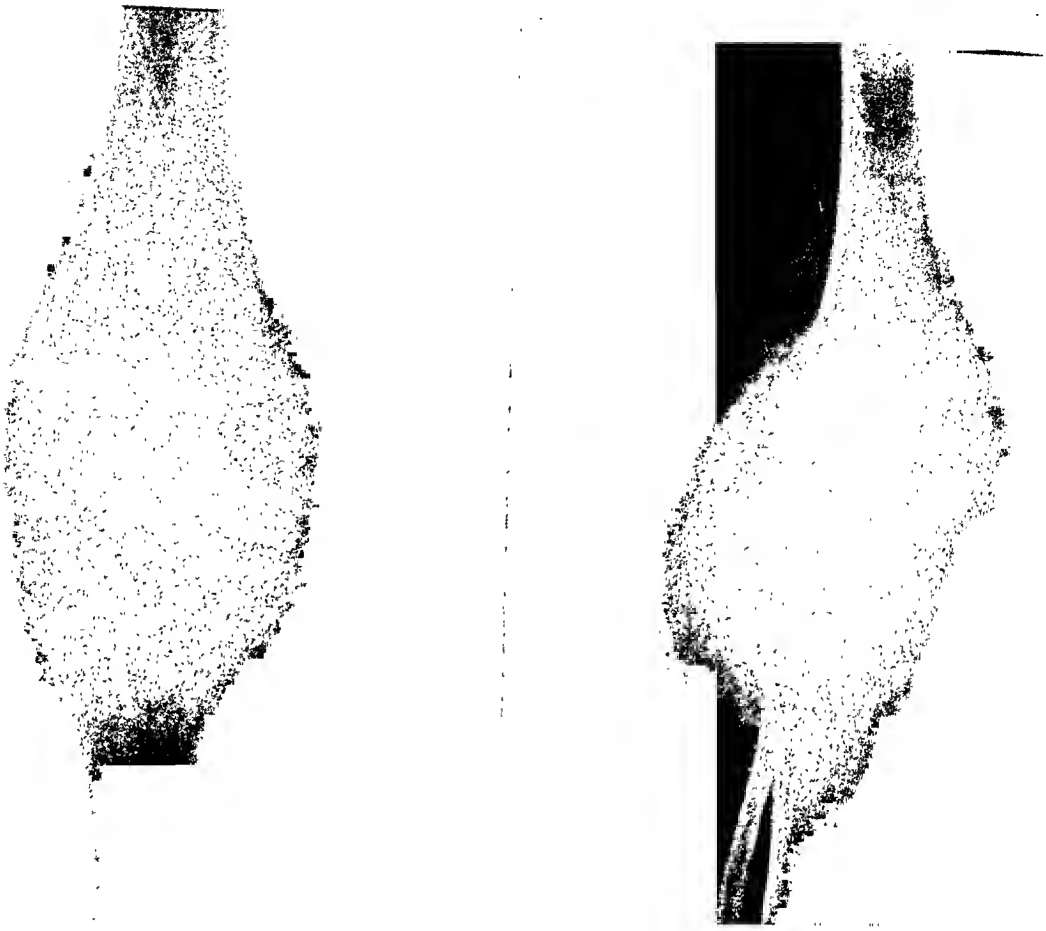

Fig. 5. D. DeM., male, aged nine. Tuberculosis of the knee joint, proved by injection into a guinea pig of material aspirated from the joint. The roentgenogram two and a half years after onset of the disease shows marked synovitis, no narrowing of the joint width, bone erosion too slight to determine its precise location.

Fig. 6. Early tuberculosis of the wrist joint, following tuberculous tenosynovitis of five to six years' duration. Roentgenogram shows small area of bone erosion on the proximal surface of the scaphoid tuberosity, just

part. This rapid and marked osteoporosis is usually lacking in tuberculosis, which is a "cold" infection, not characterized by vascular engorgement; (2) acute pyogenic joints show a distinct tendency to repair and ankylosis, features which are customarily absent in tuberculosis; (3) in tuberculosis the adjacent muscles frequently show marked atrophy, which is not the case in acute pyogenic infection.

To summarize: In acute suppurative arthritis we find acute osteoporosis, early

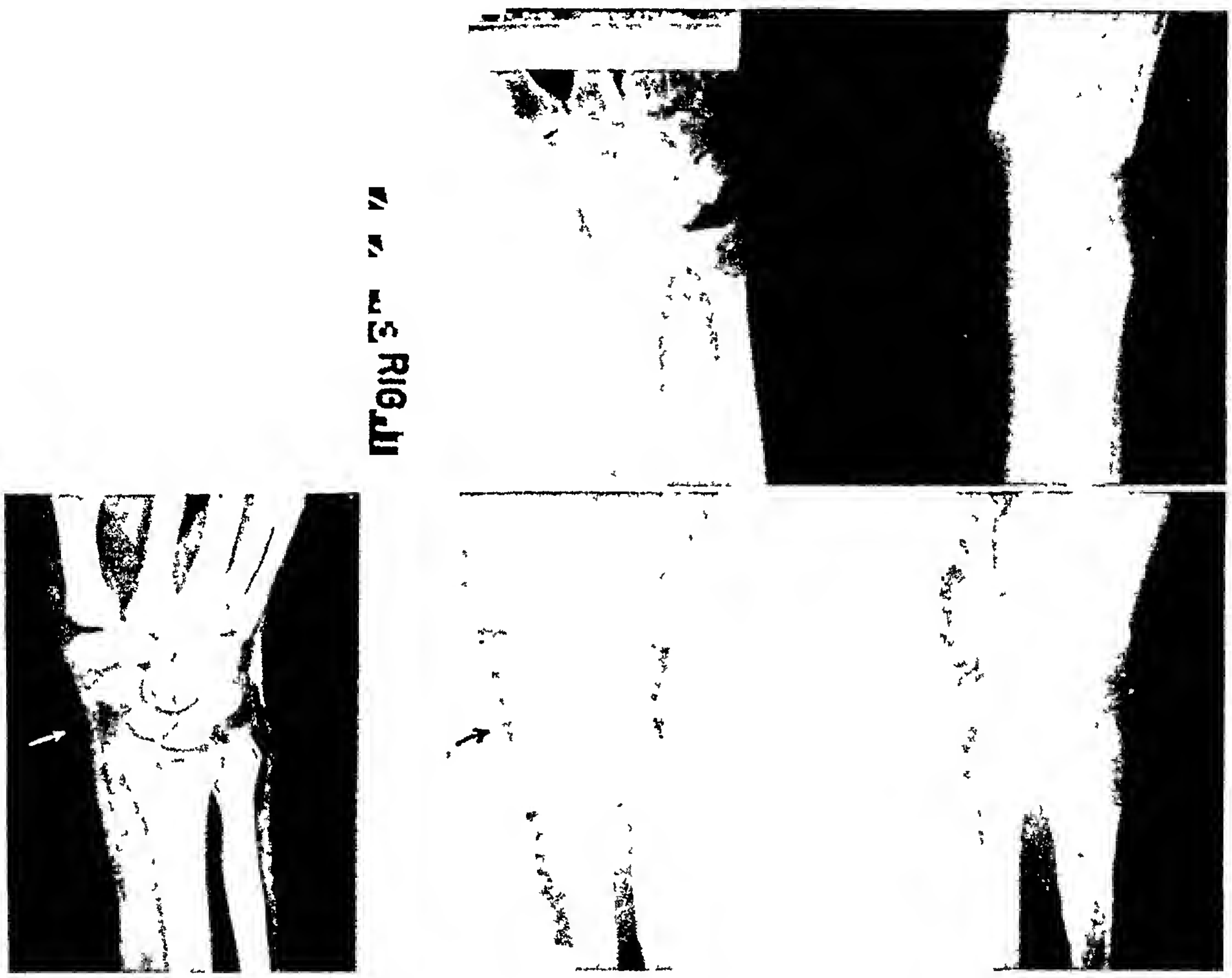

Fig. 7. Unproved, but probably early tuberculosis of the wrist joint. Shown because of similarity to the preceding case. History: S. N., female, aged forty-eight, complained of pain and swelling of the wrist for three months. Roentgen findings: Soft tissue swelling about the wrist, small area of erosion on the waist of the scaphoid bone at the margin of the articular surface, no narrowing of the joint width, widely distributed homogeneous osteoporosis, atrophy of the lower forearm. The patient left the clinic and placed herself under the care of an orthopedic surgeon in a neighboring borough. A letter from him seven months later reported that he had been unable to confirm or disprove the diagnosis of tuberculosis, but that the clinical course gave much evidence for confirmation.

Comment. The clinical course and the characteristic roentgen findings, in the light of the preceding case, seem to warrant a provisional diagnosis of tuberculosis.

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at the margin of the articular surface. No decrease in joint width. History: S. K., male, aged fifty-six, history of swelling of the wrist for five to six years. Clinical diagnosis, tuberculous tenosynovitis of flexor tendons at the wrist. Roentgen findings supported this diagnosis, but also showed the scaphoid erosion, the serious import of which none of us fully appreciated. The tendon sheaths were removed successfully at operation, and the diagnosis of tuberculosis was confirmed by the pathologist. Unfortunately the tuberculosis of the wrist joint progressed rapidly, and upon examination roentgenographically seventeen months after operation the disease was found far advanced.

decrease in the joint width, bone destruction first on the weight-bearing portions of the articular surfaces, usually little atrophy of adjacent muscles, a distinct tendency to repair and ankylosis after the early destructive stage. In tuberculosis we find less osteoporosis, late persistence of the joint width, bone destruction first peripherally on the non-weight-bearing portions of the articular surfaces, usually considerable basis of majority evidence and hope he is right.

Another confusing element in the differential diagnosis is an apparent difference in the roentgen manifestations in certain joints. In hips, for example, we have seldom observed the criteria established by Phemister; and our earliest recognition of tuberculosis in this location is usually on the basis of a more or less chronic destruc-

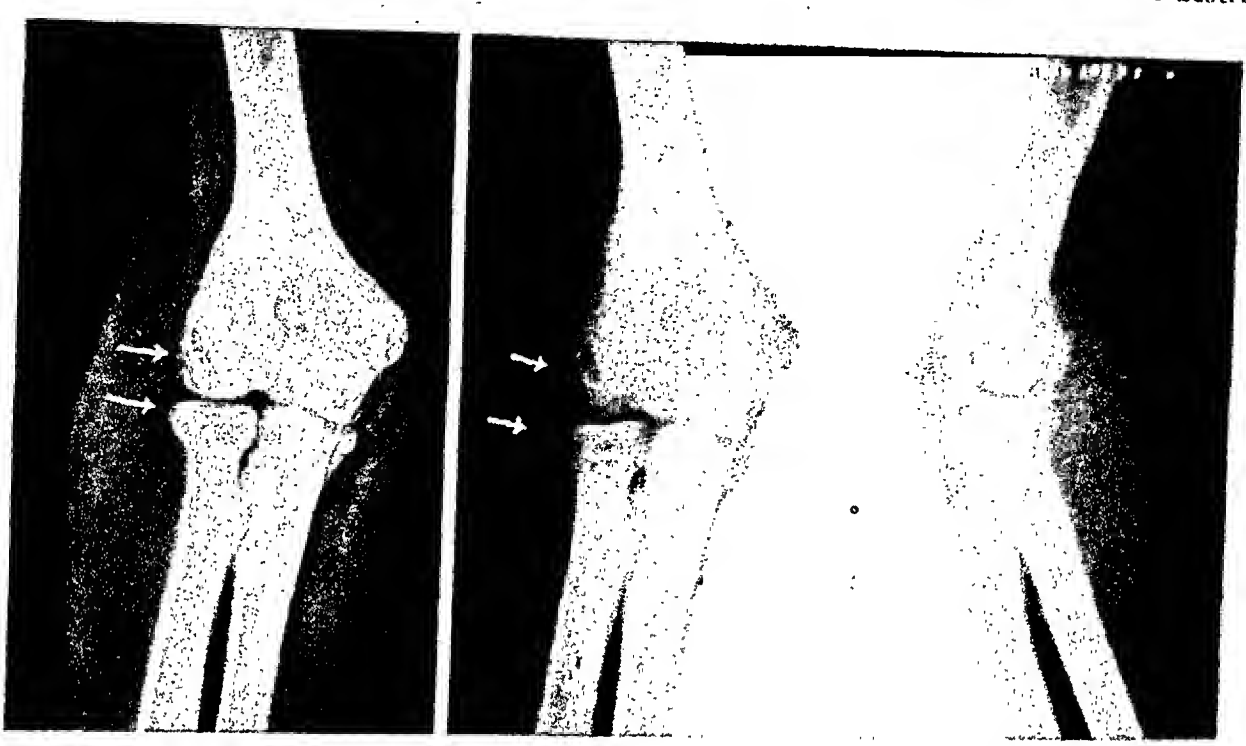

Fig. 8. Proved case, *recognizable roentgenographically as tuberculosis. Roentgen findings:* Considerable soft tissue swelling, good preservation of joint space, areas of bone erosion on the lateral aspect of the lateral humeral condyle, at the lateral margin of the capitellum, and on the lateral border of the radial head. History: S. G., male, aged fifty, with complaint of limitation of motion and swelling of the elbow for about two years. *Guinea pig inoculation of aspirated material was positive for tuberculosis.* In spite of immobilization in plaster and a winter spent in Florida, the destructive process was found to have progressed very markedly when he was examined roentgenographically sixteen months later.

muscle atrophy, little tendency toward repair and ankylosis.

If these infections would always follow their textbook patterns and show their characteristic features, recognition would be exceedingly simple. Unfortunately, however, there are so many variables due to differences in virulence in the invading organisms and reactions in the hosts, that disease characteristics often become greatly interchanged, the roentgen findings are far from clear cut, and the baffled roentgenologist can only cast his diagnostic vote on the tive disease of bone and cartilage, with little or no evidence of repair. And this, I am sure, is a fairly late stage. Although there might be an actual difference in the pattern of disease invasion of this joint, due to differences in anatomy and function, the more probable explanation is that we fail in this joint to show those early manifestations of the disease which we are successful in depicting in the more distal and much more accessible joints.

Further difficulty in diagnosis is introduced by that manifestation of joint tuber-

Fig. 9. To show that other conditions may simulate tuberculosis, and as a warning against overconfidence in roentgen diagnosis. Proved case of lymphatic leukemia of the elbow joint, presenting the roentgen characteristics of moderately advanced tuberculosis. History: C. D., male, aged fifty-three, developed pain and swelling in the right elbow three and a half months ago. About two weeks after onset, his private physician made an incision, under gas anesthesia, and pus was said to have been evacuated. Since that time the wound has drained. Upon presenting himself to the clinic the patient complained of a swollen, functionless elbow, draining slightly from a sinus. There were no systemic symptoms.

Roentgenograms (*A*) showed a markedly swollen elbow, with extensive old destruction of the articular surfaces, without repair other than slight productive changes about the neck of the radius, with preservation of the joint space. The condition was believed almost certainly to be extensive old tuberculosis. A diagnosis of lymphatic leukemia was established by blood count and examination of a lymph node excised from the axilla. Radiation treatment was given at Memorial Hospital. The patient was seen at follow-up examination eighteen months later, his general condition was found good, he had good elbow function, he had been working for a year, his blood count was still characteristic of lymphatic leukemia, the roentgenogram (*B*) showed excellent healing and no evidence of any present disease.

Fig. 10. Unproved, but beyond doubt tuberculosis of the shoulder joint, in a patient with widely distributed proved tuberculosis. Roentgen findings: Soft tissue swelling, joint width preserved, area of bone destruction and reaction at and about the medial margin of the humeral articular surface. History: F. U., Negro, aged twenty-one, was operated upon for an undiagnosed destructive and productive lesion of the tibial shaft. The disease spread into the knee joint, which was operated upon twice, and then thigh amputation was performed. Pathologist's report: Bone and synovial tuberculosis. The patient developed several other foci in the extremities, including the shoulder, and developed pulmonary involvement, with positive roentgen findings and sputum, from which he died.

culosis commonly called caries sicca. The reasons for the occasional occurrence of this quite different pattern of tuberculous invasion are apparently unknown. In our rather limited experience with it, we have

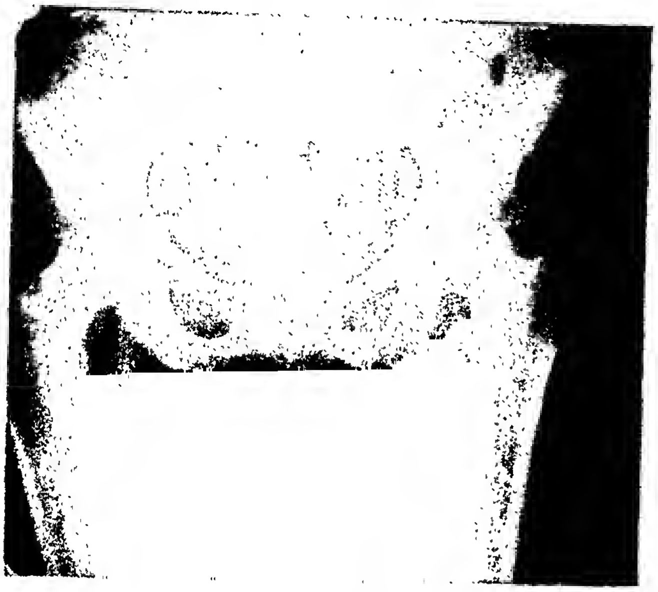

Fig. 11. Rather typical case of proved tuberculosis of the hip joint, showing that the usual roentgen diagnostic criteria are not, as a rule, demonstrable in this joint. Roentgen findings: Striking demineralization of the bones, with especially poor bone detail in the upper hemisphere of the femoral head, with good preservation of the joint width (this is often not *true*), with soft tissue swelling. This could be identified *only* as a low grade destructive type of arthritis with no repair, suggestive but not definitely positive of tuberculosis. History: F. DeG., female, aged thirty-one, came to the clinic with nine months' history of pain and stiffness in the hip. She was roentgenographed and followed in the clinic and hospital for eight months before she developed sufficient roentgen evidence to warrant surgical intervention. Microscopic study of removed tissue established the diagnosis.

Comment: In the hip joint roentgen findings pathognomonic of tuberculosis are not the rule. The disease may be suspected when there are evidences of monarticular chronic destructive infectious arthritis.

sometimes been successful in diagnosis, largely by process of elimination: a single joint, with varying degrees of rounded punched out bony erosion and rounded bony excavation in and about the joint, with fairly good preservation of cartilage, with no suggestion of repair, with little or no soft tissue reaction,—what else might it well be?

Of diseases other than acute suppurative arthritis with which tuberculosis of the joints of extremities might be confused, little need be said. The appearance of rheumatoid arthritis is quite different, and many joints are involved. There is ordinarily no confusion with neuropathic joints, where the destruction is largely mechanical. With luetic joints other than Charcot, I have little familiarity. Villonodular synovitis produces a large boggy joint, with no suggestion of bone or cartilage abnormality, and not even osteoporosis. Of rare joint involvements in leukemia, histoplasmosis,

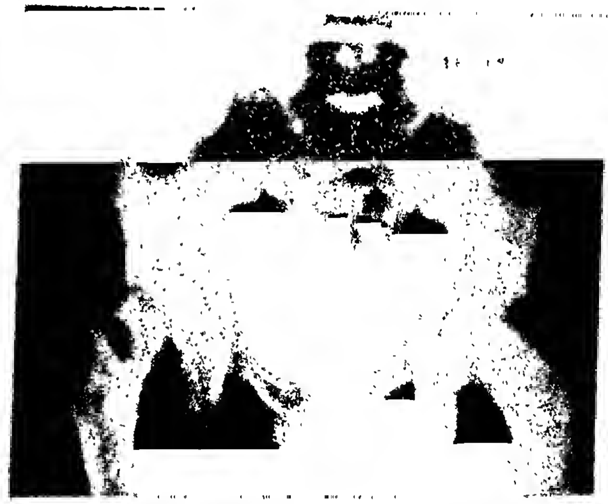

Fig. 12. Proved case of tuberculosis, classified by [illegible] as of the caries sicca type. The usual roentgen diagnostic criteria are not applicable in cases of caries sicca. Roentgen findings: Extensive [illegible] rounded punched-out areas of bone destruction in the acetabulum and femoral head, with moderate narrowing of the joint width, and [illegible] soft tissue swelling. History: N. P., male, aged fourteen, gave a history of [illegible] in the hip and knee for five years, [illegible] sufficiently severe to interfere with [illegible] or other activities. He had [illegible] physician until one month [illegible] [illegible] suggestive of caries sicca. [illegible]

and so forth, one can say only that they are confusing, they should be borne in mind, and that their diagnosis rests mostly on evidence other than roentgenologic.

SUMMARY

1. Phemister's significant work on tuberculous and pyogenic infections of the joints of extremities, so far as this applies to roentgenographic differential diagnosis, has been reviewed.

2. Roentgenographic characteristics of pyogenic (non-tuberculous) infections of extremity joints are: acute osteoporosis, early decrease in joint width, earliest bone destruction on weight-bearing portions of articular surfaces, usually little atrophy of muscles, a tendency to repair and ankylosis.

3. Characteristics of tuberculosis: less osteoporosis, late persistence of joint width, earliest bone destruction peripherally about the margins of the weight-bearing surfaces, usually considerable muscle atrophy, little tendency to repair and ankylosis.

4. These differential points appear not to apply to hip joint infections, or to cases of caries sicca.

5. Lymphatic leukemia, and probably other conditions, may simulate tuberculous arthritis.

6. Illustrative cases have been presented.*

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REFERENCES

1. Phemister, D. B. Changes in the articular surfaces in tuberculosis and in pyogenic infections of joints. Am. J. Roentgenol. & Rad. Therapy, 1924, *12*, 1–14.
2. Phemister, D. B. Effect of pressure on articular surfaces in pyogenic and tuberculous arthritides and its bearing on treatment. *Ann. Surg.*, 1924, *80*, 481–500.

* For discussion see page 354.

INTERNAL DERANGEMENTS OF THE KNEE JOINT

THE DIAGNOSTIC SCOPE OF SOFT TISSUE ROENTGEN EXAMINATIONS AND THE VACUUM TECHNIQUE DEMONSTRATION OF THE MENISCI*

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THE roentgen examination of that large group of patients with derangements of the knee joint could be made indispensable if roentgenologists would heed Carty,[3] Ferguson,[7] Lewis,[9] Dittmar,[4] Nordheim,[11] Evans,[5] and others,[10] who have proved the value of soft tissue and meniscus studies.

Among the soft structures which can be demonstrated in the knee joint are the skin, the subcutaneous layer with its large veins, the rectus femoris, the vasti, the suprapatellar space, the patellar ligament, the infrapatellar fat pad and its extensions, the gastrocnemius and hamstring tendons, the adductor muscle and its tendon, the cartilage lining of the joint, the tibial collateral ligament, the extracapsular bursae when distended, and finally, the menisci.

Special techniques, as advised by Carty,[3] are not necessary for the examination of the soft structures; Lewis[9] also held that special techniques are not essential. By limiting the routine examination of the knee to anteroposterior and lateral views, the roentgenologist is deprived of essential information which can be obtained if a longitudinal view of the patella and bilateral views of the menisci are included. If any abnormal findings are disclosed by such examinations, additional oblique and so-called intercondylar views may be added. Since the light from an ordinary view box may not have the proper intensity for revealing the soft tissue shadows, a special light source which can be regulated in varying steps of light intensities will be found useful. One of the greatest needs of the roentgenologist is a source of light in his viewing equipment which has wide variable intensities and whose field of illumination can be regulated in size and shape for optimum visualization of soft structure outlines.

The internal meniscus may be demonstrated simply by traction or abduction of the leg. It is our practice to place the patient in the recumbent position on his side, with a sand bag between the table and the lateral aspect of the knee to be examined. A horizontal roentgen-ray beam is directed anteroposteriorly through the knee while a technician forces the leg into abduction against the table top. The exposure is made two or three seconds after the initiation of abduction because, if made earlier or later, the full vacuum is not revealed due to incomplete dispersion or to filling up of the joint space with synovial fluid. A lateral view of the meniscus can be obtained as easily as the anteroposterior view, using the same technical principles, but since no additional information is derived, our routine examination is limited to bilateral anteroposterior views. No clinical significance is attached to irregular margins or defects of menisci since such changes are not uncommonly visible in the healthy knee joint. It is only non-visualization of the meniscus which carries diagnostic weight because synovial fluid in the slightest excess makes demonstration of the meniscus impossible. Nordheim[11] believed that the meniscus could not be shown if more than 5 or 10 cc. of fluid was present in the knee joint. In normal cases, the internal meniscus can be demonstrated in not more than [illegible] per cent of cases. The external meniscus can be shown in not more than [illegible] per cent. If, therefore, the meniscus cannot be [illegible]

* Presented at the [illegible]
[illegible], Sept. [illegible]

monstrated in either knee joint, it is presumed that the patient falls into the small 20 per cent group in which the internal meniscus cannot be demonstrated normally. To illustrate, suppose one is called upon to examine a football player whose knee had locked during a recent scrimmage. If the meniscus in the injured knee cannot be demonstrated while the meniscus in the healthy knee can be demonstrated, these findings are taken to indicate the presence of excess synovial fluid in the injured knee, even though there is no clinical evidence of swelling. If the meniscus in either knee

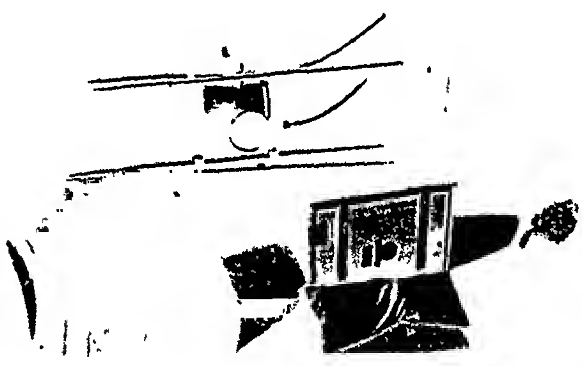

Fig. 1. Technique for the examination of the internal meniscus. A sand bag may be placed under the lateral aspect of the knee to be examined with the patient in the lateral recumbent position and while a technician abducts the extended leg by pressing the ankle towards the table top, an anteroposterior exposure of the knee joint is made, directing the roentgen-ray beam horizontally.

cannot be demonstrated, then these findings have no value.

Slight excess synovial fluid may be present without clinical detection in cases of chronic as well as acute injury or disease, so that it is our practice to make bilateral meniscus examinations a routine procedure in all examinations of the knee.

The quality of the roentgen diagnosis will depend on the care with which all the clinical facts are gathered and appraised. Presuming an intimate knowledge of the appearance of the normal soft tissue structures, in the light of a well documented history and physical examination, the slightest irregularities in the roentgenogram can be interpreted properly in pathologic terms leading to a precise diagnosis and prognosis. This averts making a roentgeno-

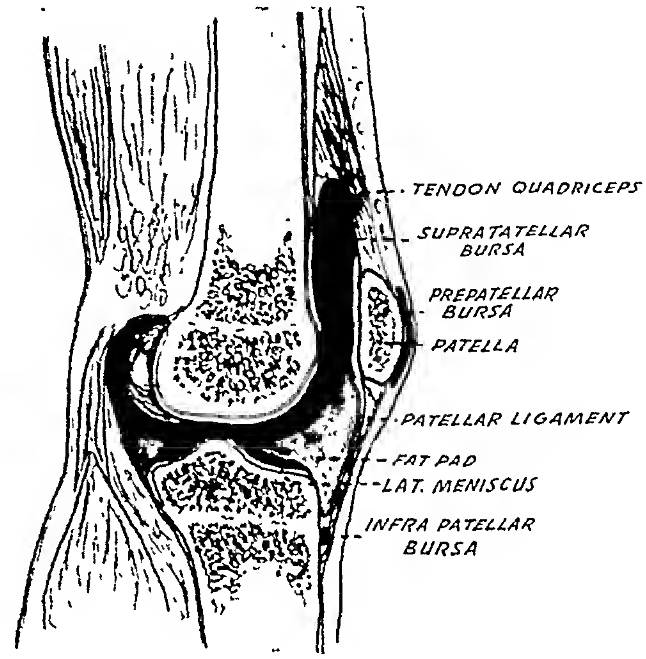

Fig. 2. Soft structures of the knee joint which can be studied roentgenographically in the lateral view.

logic report describing shadows in vague meaningless terms which hedge the diagnosis until the value of the roentgenologic

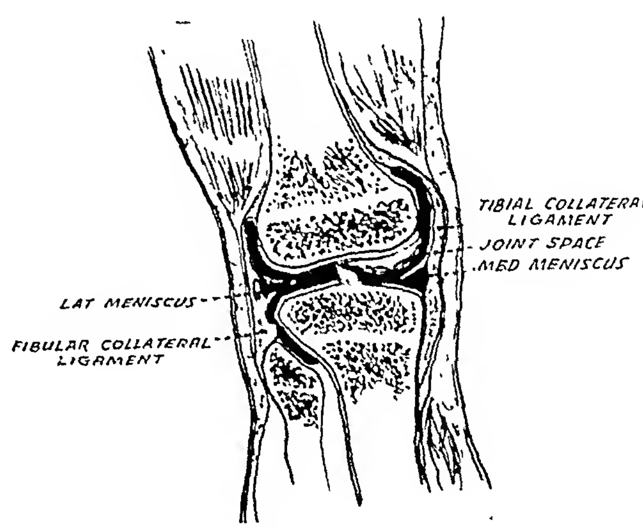

Fig. 3. Soft structures of the knee joint which can be studied roentgenographically in the anteroposterior view.

consultation has been reduced to a minimum, if not rendered discouragingly ambiguous.

The finding of slight excess synovial fluid

Fig. 4. Normal internal meniscus, tibial collateral ligament, subcutaneous layer, long saphenous vein and skin over inner aspect of knee joint.

in an acutely injured knee, evidenced by a failure to demonstrate the meniscus, suggests that the roentgenologist look for abnormal changes in the soft structures if he is to report findings which explain the patients' symptoms. There may be an actual fracture or loosening of the attachments of a meniscus, especially if there is swelling of the tibial collateral ligament; or there may be a swelling of the tibial collateral ligament resulting from a sprain. The structures in the region of the tibial collateral ligament are seen best in the anteroposterior and lateral views. If both knees are examined, the untrained observer can compare the injured with the healthy side and readily determine the slightest swelling in this area. This is important because most actual injuries to the internal meniscus are associated with sprain and swelling of the tibial collateral ligament. In cases where there has been damage to the anterior horn of the internal meniscus, there is frequently an associated injury to the inner alar fat pad. When all the symptoms of internal derangement are present except that of locking, damage to the alar fat pad might be the explanation and this can be seen as a swelling on the inner side of the patella in the longitudinal view. If there has been only a rupture or a sprain of the tibial collateral ligament, a localized swelling of the ligament may be seen corresponding to the point of greatest pain and tenderness. Occasionally, the demonstration of the meniscus in a swollen knee will indicate the absence of excess synovial fluid; the swelling in these cases may be found to be due to subcutaneous edema, enlargement of bursae, periosteal damage or hemorrhage, a torn ligament, cysts, or hypertrophied fat pads. Such precise differentiation, not possible by physical examination, can be made by careful roentgen examination of the soft structures.

INTERNAL DERANGEMENTS OF THE KNEE JOINT

The attachments of the menisci vary widely and this markedly influences the symptomatology. Thus one individual may

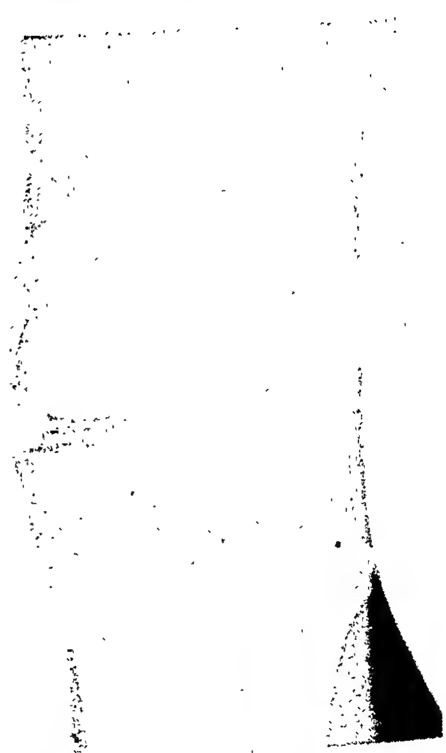

Fig. 5. A sagittal defect of the internal meniscus suggesting a bucket-handle fracture, but this knee joint was symptomless and supposedly healthy. This patient was examined because of an injury to the opposite knee which revealed a prepatellar contusion resulting from a bump of the knee against the dashboard of an automobile.

wrench his knee severely without displacement of the cartilage and another may have displacement simply with ordinary use on a staircase or on the dance floor. The congenital anomalies naturally produce symptoms early in life and those that appear in childhood are apt to be due to these congenital irregularities, especially common in the external disc. The highest incidence of symptoms occurs in the age group between fifteen and twenty-five years. In a large number of cases encountered in a relatively short time at a Naval Training Center recently, more than 60 per cent of the cases fell into this age group; but even when the statistics are culled from the civilian population, similar findings have usually been made. Athletics is the principal immediate cause of symptoms in most cases, usually football, basketball or drill maneuvers. In some occupations, as mining, especially in the low gallery mines of England where miners work in a kneeling position with their toes turned out, there is also a high incidence of chronic internal derangement of the knees.

The initial symptoms may be sudden, severe and intense and then become progressively less disabling with each recurrence; or the first symptoms may be almost insignificant, but with each recurrence they may become progressively more severe. Again, the symptoms of the first attack may be mild and change slightly in character during the chronic recurrent phases of the disease. Finally, in some instances, the initial symptoms may be severe and remain so with few remissions. These various trends in the course of the disease depend chiefly on the structural characteristics of the joint ligaments and the nature of the initiating mechanism. An intense acute onset is due usually to concomitant damage to the ligaments. Locking, which does not occur until late, may be the result of progressive stretching of the ligaments with each recurrent attack. Whether locking occurs early or late in the course of derangements, the acuteness of the symptoms is usually due to the initial sprain and swelling of the ligaments. Some care must be exercised in

Fig. 6. Internal derangement of the knee joint resulting from a football injury which caused locking. There is slight swelling of the synovia and of the mid-portion of the tibial collateral ligament. The presence of slight excess fluid in the joint space precluded demonstration of the meniscus by the "vacuum technique." At operation, the surgeon (Dr. M. A. Stevens) found a detachment of the posterior horn of the internal meniscus.

getting the facts about locking; limitation of motion is sudden and immediate in disc injuries whereas limitation of motion due to effusion, pain or spasm comes on gradually. Conversely, a sudden "unlocking" is characteristic of a released interposed torn meniscus fragment, while gradual restoration of full knee motion is associated with resolution of a synovial effusion and muscular spasm. In football injuries true locking occurs in 60 to 80 per cent of cases but the incidence from other accidents, such as a fall, a blow or a twist is relatively low, probably less than 25 per cent. Tenderness is usually localized over the site of the torn portion of the meniscus, whereas the tenderness which may be found with effusion is usually not localized. The mere presence of local tenderness is not always indicative of a torn cartilage, because local tenderness may also occur over a tear of the tibial collateral ligament or over a localized contusion. Since all these conditions may be associated with synovial effusion, the

differential diagnosis of a torn meniscus may be difficult or even impossible in the early stages, especially in those cases where there is no history of locking. In a recent analysis of 84 cases of ruptured menisci proved by operation, the history disclosed locking in 60 per cent, "giving way" of the knee in over 20 per cent, pain in slightly under 20 per cent and effusion in about 20 per cent.

A careful clinical examination may lead to the proper diagnosis without a roentgen examination, but its omission can deprive the clinician of extremely valuable information. In uncomplicated injury to a meniscus, swelling of the synovia with excess synovial fluid, swelling of the tibial collateral ligament and inability to demonstrate the internal meniscus by the vacuum technique may be the only roentgen findings in support of the clinical diagnosis; but it is the absence of other roentgen evidence of disease which may be of even greater importance to the clinician in the treatment of these cases.

LOOSE BODIES

Loose bodies may be single or multiple, pedunculated or free, laminated or nonlaminated and they may originate from unorganized fibrin, necrotic portions of synovial membrane, organized connective tissue, cartilage or bone. Hemorrhage into a joint may be a source of fibrin, later forming a loose body. Necrotic synovia, part of an arthritic process, may be another source of loose bodies. This is quite common in tuberculosis which is associated with loose bodies that have ragged margins and shaggy surfaces at first, but which soon become smooth and glistening, not unlike melon seeds in appearance. Some loose bodies originating from hypertrophied synovial fringes may be due to trauma, synovitis or osteoarthritis; others originate from hypertrophied fat pads as lipomas before becoming detached. Loose bodies due to bone or cartilage are usually of arthritic origin, but they may come from normal joint structures from which they have become detached by direct or indirect trauma. Many chondromas are of synovial origin. Shattock,[12] in 1889, pointed out the derivation of other loose bodies from areas of hyperplasia in cartilage in which central ossification subsequently occurs. Of the arthritic causes, tabes produces the largest loose bodies whereas infectious non-tuberculous forms of arthritis may produce only small bony sequestra or flakes of necrotic articular cartilage.

Loose bodies occurring in normal joints by detachment of the articular surface are seen more frequently in males than in females, and usually between fifteen and twenty-five years of age. The convex surface of these bodies, which may be oval and about the size of an almond, is apt to be smooth, while the opposite surface is rough and wrinkled. They arise usually from the under surface of the inner femoral condyle or from the posterior surface of the patella and while they are commonly single, two or more are seen occasionally in the knee joint. These bodies may be only incompletely detached, but when fully detached and free, a defect in the articular surface at the site of their origin may be seen having the same size and shape as the body; this condition is often seen bilaterally.

Loose bodies due to synovial chondromas may be single, multiple or diffuse, pedunculated or free. Although these bodies may arise from cartilage cells normally present in the synovia, they usually come more often from the connective tissue cells of the membrane. The single chondroma may or may not be laminated and the surface is usually smooth, even if made up of low lobulations. The laminated chondromas tend to occupy pouches or recesses of the synovial membrane, and because they usually grow larger than most other loose bodies, they seldom get caught between the articular surfaces. Fisher[8] believed that some loose bodies may be due either to direct traumatic detachments or to separation of portions of the articular surface by a pathologic process following injury, similar to a localized form of traumatic osteo-

arthritis. Shattock[12] called these formations "epiarticular ecchondroses" while König called the condition "osteochondritis dissecans." The concept is held by many that trauma is at least one factor in this condition just as it is conceivable that by indirect strain with violent pull on the cruciate ligaments, detachment of a small portion of the articular surface might be effected.

The clinical diagnosis of loose bodies is based on the history of sudden attacks of severe pain, often followed by swelling or momentary locking, due to the body becoming suddenly nipped either between the articular surfaces or between the capsule and joint ends. The momentary locking may be associated with the presence of external swelling, and the patient may make this observation and find it necessary to push the body inward to free the joint. Large bodies may give rise to less acute symptoms since they are unable to engage themselves between the articular surfaces. Those bodies which remain firmly attached to the synovia or in pockets of the articular surface without getting pinched between the articular edges seldom if ever cause symptoms.

The roentgen demonstration of loose bodies in anteroposterior and lateral views of the knee is not easy even when they are calcified or ossified. The longitudinal view of the patella, oblique and lateral views in extension and flexion in over-exposed films are necessary to furnish all the available roentgenologic evidence in the detection of loose bodies, especially in those bodies still undetached in the cartilage layer. Thickening of the synovia due to diffuse hyperplasia can be seen by careful attention to the soft tissue shadows, and this furnishes a clue to the presence of chondromata which might be felt but which cannot be seen in the roentgenograms. Other invisible loose bodies, derived by trauma from the articular cartilage, may be suspected after finding defects in the cartilaginous outline of the femoral condyles and the patella, especially in the longitudinal view. The meniscus examination usually rules out the presence of an injury or a loose body and so, these two conditions, which mimic each other so often, may be differentiated. Having excluded the presence of a ruptured meniscus and having demonstrated the presence of a loose body, the roentgen examination alone is responsible for an accurate differential diagnosis in this large group of derangements of the knee joint caused by loose bodies.

Fig. 7. An old rupture and chronic sprain of the tibial collateral ligament. There is periosteal proliferation and calcification of hemorrhagic infiltration around the lower attachment of the swollen tibial collateral ligament. A football injury, which occurred one year prior to this examination, resulted in marked swelling of the knee during the first twelve hours following the injury, but this was not associated with locking. This swelling subsided with rest after a few days, but there have been intermittent recurrences of similar swelling following slight twists or excessive strain during the year preceding this examination. Pain and tenderness have always been localized over the medial aspect of the knee joint.

SPRAIN OR RUPTURE OF THE TIBIAL COLLATERAL LIGAMENT

The tibial collateral ligament is a broad flat membranous band situated nearer to the back than to the front of the joint. Its attachments extend from the abductor

Fig. 8. Organized ossifying periostitis around injured upper attachment of the tibial collateral ligament. The meniscus could be demonstrated, indicating absence of excessive synovial fluid. This knee had been injured seven years prior to this examination in a football accident which caused immediate swelling, limitation of motion, pain and tenderness, especially over the inner aspect of the knee joint. No locking occurred. Since the initial injury, there have been recurrent episodes of giving way of the knee joint followed by transient swelling.

tubercle above to the tibial tuberosity below. The posterior oblique fibers are short, inserting into a groove of the tibia above the semimembranosus. The anterior portion is flat, about 4 inches long, inclining slightly forward as it descends. The internal meniscus is not bound down to the tibial collateral ligament as usually described in textbooks of anatomy. There is usually a loose attachment between the anterior portion of the ligament and the meniscus, often with an interposed bursa, such as is normally present in apes. Only the posterior portion of the ligament is firmly attached to the peripheral border of the internal meniscus.

If excessive rotation of the femur occurs, especially during flexion when excessive abduction of the leg is more readily produced, tears of the ligaments are more apt to occur, which often takes place in conjunction with injuries or ruptures of the menisci. Sprain or rupture of the tibial collateral ligament causes pain and tenderness on the inner side of the joint over the attachments of the ligament. The short posterior or oblique portion of the ligament is likely to be sprained when there has been injury to the internal meniscus. If signs of an injured internal cartilage fail to develop, a ruptured tibial collateral ligament may be diagnosed by the persistence of swelling, pain and tenderness on the inner aspect of the knee. Recurrences are not infrequent when the original injury has been inadequately treated. A minor twist or turn is sufficient to bring on a recurrence, causing a sudden "giving way" of the joint followed by swelling, and a chronic condition may then supervene with the evolution of a chronic arthritis. Additional symptoms may become evident such as increasing abduction of the leg and thickening of the tibial collateral ligament due to fibrosis or ossifying periostitis. In severe injuries,

Fig. 9. Osteochondritis dissecans with slight thickening of the synovia. The meniscus could not be demonstrated.

there may be an avulsion of the periosteum where the ligament is attached to the bone. This occurs more frequently from the femoral than from the tibial attachment and when this condition heals, it resembles Pellegrini-Stieda's disease.

The roentgen findings in the acute phases of injury to the tibial collateral ligament include visualization of soft tissue swelling around the knee, more marked on the inner aspect. Swelling caused by contusion and edema is slight, but swelling caused by hemorrhage is apt to be marked. Synovitis is usually present with ligamentous injuries and the slightly increased synovial fluid which is present precludes demonstration of the meniscus. Definite swelling or thickening of the injured portion of the tibial collateral ligament can be demonstrated more easily by comparison with the opposite knee in the roentgenograms. This is best seen in the anteroposterior and oblique views. In the chronic phase of sprain or rupture, fibrous thickening of the ligament may be visualized, sometimes with adjacent fibrosis in the perifocal overlying subcutaneous tissues. Rarely is ossifying periostitis present in the region of the ligamentous insertions.

Fig 10. Longitudinal patellar view of osteochondritis dissecans (same case as in Fig. 9).

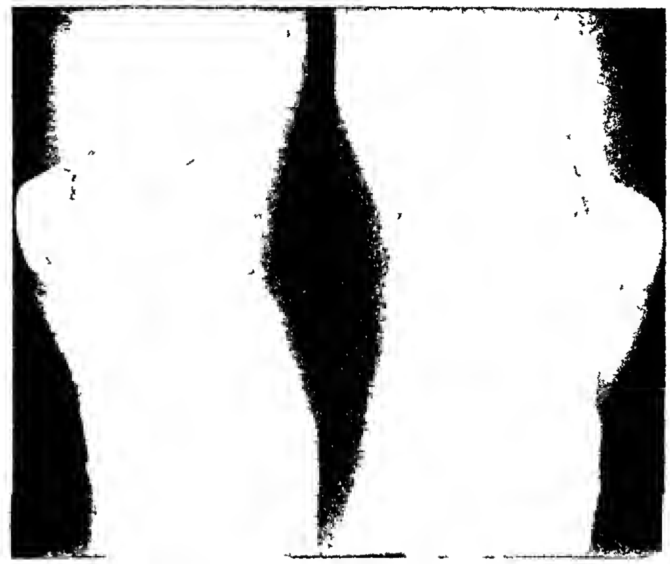

Fig. 11. Bilateral synovial chondromas with thickened synovia in a patient whose knees give way intermittently without locking.

PERI-ARTICULAR BURSITIS

The many bursae about the knee are not demonstrable normally by roentgen examination, but they may be seen when they fill with fluid as the result of bursitis. Slight swelling of the suprapatellar bursa, and the synovia with which it is continuous, is easily detected roentgenographically. This bursa is quite distensible and it can contain a surprisingly large amount of fluid. The prepatellar bursa is readily visualized when it contains only minimal amounts of fluid. The clinician is sometimes unable to exclude a co-existing synovitis in the presence of a prepatellar bursitis, but by the use of the technique to demonstrate the meniscus and by examination of the suprapatellar bursa and the patellar fat pad, the roentgenologist can easily furnish the correct information. Swelling of the pretibial bursa, not infrequently found with Osgood-Schlatter's disease, is nicely delimited by roentgen examination. Cysts of the posterior bursae or synovial membrane may be visualized if careful inspection of the soft tissue outlines is made routinely. These cysts may arise from any bursae, but they are generally encountered in the posterolateral aspect of the knee. With extension and flexion of the knee, these cysts may change in size

and shape, being directly connected with the synovial space. Lateral examination of the knee in flexion and extension may confirm these clinical findings, an important consideration to the surgeon called upon to treat the case.

Fig. 12. Hypertrophy of the inner alar fat pad. The demonstration of the internal meniscus confirms extracapsular limitation of condition.

CYSTS OF THE MENISCI

Cysts of the menisci, particularly of the external meniscus, is a well recognized condition. They are hemispherical masses attached to the periphery of the meniscus and they are comprised of a series of well defined spaces filled with a thick transparent mucoid material. Bristow found in them no evidence of inflammation or hemorrhage and believed that trauma plays no part in their causation. He concluded that they represent degenerative cysts comparable to ganglia, arising in the synovial and extrasynovial fatty and areolar tissue as well as in the fibrocartilage. Fisher believed that the external meniscus is usually involved because it is the only cartilage that normally receives a partial covering of synovial membrane where it is crossed by the popliteus tendon; and it is at this crossing where these cysts are found. He ascribed direct or indirect trauma as their cause through strain exercised by the popliteus tendon.

The local swelling and pain caused by these cysts can be detected clinically, but careful study of the soft tissue shadows by the roentgenologist leads to a more accurate diagnosis. The demonstration of the meniscus in these cases rules out the presence of a torn or displaced meniscus, which is not done with ease clinically.

Fig. 13. Cyst of the external meniscus.

NEOPLASMS

The malignant nature of bone tumors can be determined not only by searching the cortex and periosteum for evidence of a break-through into the adjacent soft tissues, but also by assiduous inspection of the soft tissue outlines for signs of invasion. Tumors arising in the soft structures, like xanthomas, angiomas and fibrolipomas, are

easily overlooked unless routine scrutiny of the soft tissues is a confirmed procedure.

MISCELLANEOUS CONDITIONS OF THE SOFT TISSUE

Varicosities of the popliteal and long saphenous veins and of some of their branches can be seen in roentgenograms without difficulty. Contusions with extracapsular edema or hemorrhage can be distinguished from intracapsular swellings and confirmed by the demonstration of the meniscus. Conversely, traumatic synovitis can be separated from contusion or other extracapsular swellings, and confirmed, by failure to demonstrate the meniscus because of the presence of excess synovial fluid. This differentiation between intra- and extracapsular causes of knee swellings by the roentgen examination can be a source of much satisfaction to both the clinician and roentgenologist.

SUMMARY

1. The technique for the examination of the menisci is discussed.

2. The value of the roentgen study of the soft tissues of the knee in conjunction with examination of the menisci is stressed in achieving accurate diagnoses of derangements of the knee joint.

3. A review is made of conditions which simulate internal derangements of the knee joint, and the roentgen appearances of the menisci and soft tissues in each of these conditions are described.*

* For discussion see page 354.

REFERENCES

1. Abbott, L. C., Saunders, J. B. deC. M., Bost, F. C., and Anderson, C. E. Injuries to ligaments of knee joint. *J. Bone & Joint Surg.*, 1944, *26*, 503–521.
2. Brantigan, O. C., and Voshell, A. F. Tibial collateral ligament; its function, its bursae and its relation to the medial meniscus. *J. Bone & Joint Surg.*, 1943, *25*, 121–131.
3. Carty, J. R. Soft tissue roentgenography; anatomical, technical and pathological considerations. Am. J. Roentgenol. & Rad. Therapy, 1936, *35*, 474–484.
4. Dittmar, O. Der Kniegelenk-Meniskus im Röntgenbilde. *Röntgenpraxis*, 1932, *4*, 442–445.
5. Evans, Wm. A , Jr. Roentgenological demonstration of true articular space; with particular reference to the knee joint and the internal semilunar cartilage. Am. J. Roentgenol. & Rad. Therapy, 1940, *43*, 860–864.
6. Felsenreich, F. Darstellung des verletzten Meniscus medialis im Röntgenbild bei veralteter Kreuzband- und Seitenbandverletzung. *Röntgenpraxis*, 1936, *7*, 332–333.
7. Ferguson, A. B. Roentgenography of tuberculosis of the joints. *J. Bone & Joint Surg.*, 1937, *19*, 653–656.
8. Fisher, A. G. T. Internal Derangements of the Knee-Joint. Second edition. H. K. Lewis & Co., Ltd., London, 1933.
9. Lewis, R. W. Roentgenographic soft tissue study in an orthopedic hospital. Am. J. Roentgenol. & Rad. Therapy, 1942, *48*, 634–642.
10. Löhr, R., and Hellpap, W. Der Kniegelenkspalt im Röntgenbild. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1938, *58*, 45–56.
11. Nordheim, Y. Eine neue Methode, den Gelenkknorpel, besonders die Kniegelenkmenisken, röntgenologisch darzustellen (ohne Zuhilfenahme eingespritzten Kontrastmittels). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1938, *57*, 479–495.
12. Shattock, S. G. Pedunculated chondroma removed from the knee-joint. *Tr. Path. Soc., London*, 1889, *40*, 256–262.

POST-TRAUMATIC PARA-ARTICULAR CALCIFICATIONS AND OSSIFICATIONS OF THE ANKLE

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POST-TRAUMATIC calcifications and ossifications about the joints are a problem of prime importance and are frequently encountered in military personnel due to the rigorous physical training program. Several types of post-traumatic deposits have been described, indicating the multiplicity of the roentgenographic appearances. Ossifying myositis, myositis ossificans progressiva, avulsion sprain fracture and peritendinitis calcarea are some of the names applied. The entity in the knee has been thoroughly described by many authors.[12,16,17,25] Little has been said in published literature regarding these new formations in the region about the ankle following trauma, yet this area suffers as many injuries as does the knee. Lewin[17] in his recent textbook on "The Foot and Ankle" makes only slight reference to this particular condition. I have recently seen several cases of post-traumatic para-articular involvement of the ankle joint and the marked similarity of the roentgenographic findings at the site of the ankle to this syndrome of the knee merits a review of the etiological factors and pathology of post-traumatic calcifications and ossifications advanced by the various authorities.

Pellegrini[21] in 1905 and Stieda[23] in 1907 originally described the syndrome in the knee, with the former stating that dual processes of periosteal proliferation and direct metaplasia of ligamentous structures existed, while the latter contended that it was the result of a periosteal stripping from the femur. An editorial[?] in this Journal in 1932 was apparently the first mention in English literature of Pellegrini-Stieda's [illegible] of post-traumatic calcification of the collateral tibial ligament, and Kulowski[16] in 1933 published an article on the subject. Later, in 1942, he[17] presented a graphic and comprehensive dissertation on the same subject with the conclusion of the para-osteal origin of the new growth.

Köhler[15] expresses the opinion that the bony shadows may be due to ossification of connective tissue; however, a tear of the periosteum may occur. Usually no defect in the bones can be observed. Some observers[2,5,11] feel that organization of a hematoma in the connective tissue after rupture of small blood vessels may account for the lesion. One cannot eliminate the fact that formation of bone may occur on a connective tissue basis. Ferguson[5] makes the statement that trauma may cause stagnation of fluid in the muscle or fibrous tissue with a resulting calcification. The deposits may be somewhat diffuse and amorphous, later becoming more dense, sharply defined and contracted. If resorption occurs, the deposit loses its density and disappears. If resorption does not occur and is subject to strain and stress, bone formation may result. The tendency to calcification of stagnant fluid, blood or lymph in muscular tissue is confined usually to the muscle involved, with an axial distribution and a fanning out in the direction of the muscle fibers.

The separation of a flake of bone from the surface was suggested by [illegible] as the cause of the deposits [illegible] three to four weeks after the injury. He [illegible] lateral malleolus of the fibula [illegible]

[illegible]

Two authors, Geschickter and Copeland,[11] definitely state that, histogenetically, the source of new bone is fibrous strands in the muscle, or tags of precartilaginous connective tissue of embryonic origin which is displaced from the primitive periosteum. A hematoma may be the important antecedent to the ossification. Dean Lewis has been quoted as stating that stripping of the periosteum due to injury is the source of the new bone which is formed at this site. These authors maintain that this would account for some types, but not for the myositis ossificans derived from cartilage. The mottled appearance of the calcification extending into the muscle seems to disprove that periosteum to any degree has been displaced for the reason that as a limiting membrane of ossification it tends to produce a rather circumscribed bone lesion. Their opinion is that injured vessels supplying the area traumatized may account for the increased calcified deposition with a chemical background stimulating bone formation.

That bone formation of a heteroplastic character may begin as a course either of cartilage or fibrous matrix is well recognized. The vascular increase in the cartilage with ossification about the small vessels indicates osteoblastic activity. The strands of connective tissue attempt to become hyaline with osteoblasts influencing calcification of the osteoid tissue, later followed by true bone. The process is one of metaplasia, and fibroblasts assume the function of osteoblasts. Finder,[9] in 1937, presented excellent microscopic evidence of the formation of heterotropic bone and quotes the work of Freund[10] and his theory of mechanical irritation of tissue by edema causing calcification and osseous formation. Epstein[6] and his co-workers found metaplastic bone formation in advanced calcification.

Ewing[7] believes that several conditions may influence the osteoblastic tendencies in fibroblasts: (*a*) the new bone formation results from osteoblasts wandering away from the periosteum; (*b*) calcified deposits occur frequently in ossification of necrotic tissue; (*c*) actively productive inflammation with organization of dead tissue and hemorrhage is essential in the ossification of muscle tissue after trauma; (*d*) there may be special predisposition to calcification and ossification, possibly related to the disturbance of calcium metabolism.

The concepts set forth by Barr[1] regarding all phases of abnormal calcification have been emphasized by Ghormley,[12] and give the following as local causes contributing to the deposition of calcium: (*a*) fatty degeneration; (*b*) formation of phosphoric acid in the tissue; (*c*) combination of protein with calcium (not proved); (*d*) alkalinity of dead and dying tissue. Barr further adds that calcified deposits are probably not compcsed of a single substance. Burge[4] and his associates advanced the hypothesis that active injured and dying tissues are electronegative to inactive and uninjured sound tissues. They showed experimentally that injury renders tissue electronegative to the uninjured portion and that calcification may result from the combination of positively charged calcium ions of the blood with negatively charged phosphate ions of the injured tissue.

Klotz[14] demonstrated the essential mechanism of calcium deposition which is always preceded or accompanied by the formation of soaps in the degenerating tissue, to which calcium is immediately attracted from the body fluids. Hitchcock[13] stated that these soaps may be found in the peripheral zone of the calcareous infiltration while calcium is still being laid down, even when the process is extensive. Replacement of the fatty acid by the stronger phosphoric and carbonic acids rapidly ensues, giving rise to the more stabile calcium phosphates and carbonates of which these deposits are largely comprised. Hitchcock described calcium deposits about the various joints initiated by trauma and vaguely mentioned the ankle as one location where this may occur. The consensus of many workers is that calcium deposition in these related conditions does not mean a disturbance of generalized calcium metabolism.

A brief survey of the anatomy of the ankle as a hinged joint is in order. The talus, the tibia and the fibula are the bony components of this joint. The distal ends of the tibia and fibula are strongly bound to each other by the interosseous ligament which fades upward into the interosseous membrane. The anterior and posterior malleolar ligaments and the inferior transverse ligament assist in the syndesmosis. The thin ligamentous articular capsule surrounds the joint and is attached above to the articular margins of the malleoli and the tibia and below to the articular margin of the talus. The deltoid ligament on the mesial aspect and the external lateral ligament (the anterior and posterior talofibular and calcaneofibular ligaments) on the outer aspect flank the joint on these surfaces. The tendons of the tibialis posterior, flexor digitorum longus and the flexor hallucis longus support and reinforce the ankle joint posteriorly. These are encompassed in mucous sheaths and bound down by the ligamentum laciniatum. The posterior tibial vessels and the tibial nerve also pass beneath this fibrous band which extends from the tibial malleolus to the margin of the calcaneus. The strong tendo achillis, arising from the gastrocnemius and soleus muscles, is attached to the posterior surface of the calcaneus with an interposed bursa between the tendon and the bone. Areolar and adipose tissue fills the space between the Achilles tendon and the structures on the posterior aspect of the tibia. This zone, roentgenographically, has been named by us the *supracalcaneal triangle* for lack of a better term, with the boundaries, the anterior border of the tendo achillis, the posterior aspect of the tibia and the contiguous soft tissue, and the base, the posterosuperior surface of the calcaneus. Superficially, it is marked by prominent lateral depressions just above the heel. Anteriorly, the transverse crural ligament binds down the mucous sheathed tendons of the extensor digitorum longus, extensor hallucis longus, peroneus tertius, tibialis anterior and the anterior tibial vessels and deep peroneal nerve. Another ligament, the cruciate, can be found just below the transverse crural also enveloping these tendons on the anterior aspect of the ankle. The peroneal retinacula (external annular ligament) embraces and fastens down the tendons of the peroneus longus and brevis laterally. The prominent malleoli are readily observed and can be palpated. Between the medial malleolus and the anterior tibial muscle, a small indentation in the soft tissue can often be seen with a similar concavity between the lateral malleolus and the peroneus tertius. These depressions indicate the level of the ankle joint. When intra-articular pathologic involvement exists, they are smoothed or bulged out.

Trauma is the predisposing factor for the production of para-articular calcification and is elicited in the history. The individual may have suffered a minor injury such as a sprain several weeks before, or a severe wrench may have occurred which at that time suggested the possibility of a fracture. Pain of considerable intensity persists long after the injury and initial treatment, and varies from a dull throb to one of lancinating character. The patient complains that walking causes discomfort even to the point of inability to bear weight. Usually some edema and soft tissue thickening are present. There is a definite restriction of motion and an aggravation of the pain on manipulation of the joint. Localized tenderness exists behind the malleoli with some obliteration of the lateral depressions anterior to the Achilles tendon. The soft tissue swelling is of the indurative type with but little pitting possible. No mass or calcified tumor is palpable. With such a picture, one should then suspect the possibility of para-articular calcification or ossification.

The absolute diagnosis of this para-articular syndrome can only be made by serial roentgen studies. At the time of the injury, the roentgenogram usually reveals no osseus involvement, with only soft tissue thickening and infiltration about the joint. The triangular dark shadow described above the os calcis posteriorly and

called the supracalcaneal triangle can be encroached upon or obliterated as the result of hemorrhage or exudate which may be intracapsular or extracapsular, or both. Subsequent roentgenograms after an interval of three to four weeks will show the deposits of calcium. These can be found paralleling the surface of the posterior malleolus of the tibia, the superior anterior aspect of the talus, or along the lateral margin of the fibular malleolus, with a definite clear space between the calcification and the bone, indicating the para-osteal origin of the formation. Calcified particles are often seen between the fibula and tibia and laid down in the interosseous membrane. The appearance of the calcifications is variable with a prevalence of the crescent shape of the deposit opposite the posterior lip of the distal end of the tibia. Many are linear at other sites. Calcification in a hematoma is usually of rather diffuse appearance with the deposits irregular and amorphous and confined to the mass density of the hematoma. The formations of calcium initially are amorphous which may ossify with trabecular structure permeating the new growth. In this respect alone can calcification be differentiated roentgenographically from ossification. Later studies may reveal a fusion between the ossified density and the adjacent bone. At this stage, the similarity to a traumatic arthritis or a healed avulsion sprain fracture is indistinguishable.

The classification by Petrignani[22] for the knee of the two main types of para-articular involvement can well be applied to the ankle and depends upon the stage of development as to the type: (*a*) the evolutive; (*b*) the stabilized. The former type of involvement appears fuzzy and has hazy margins with different degrees of opacification in the adjacent connective tissue. The stabilized type is a mature, contracted and well defined density.

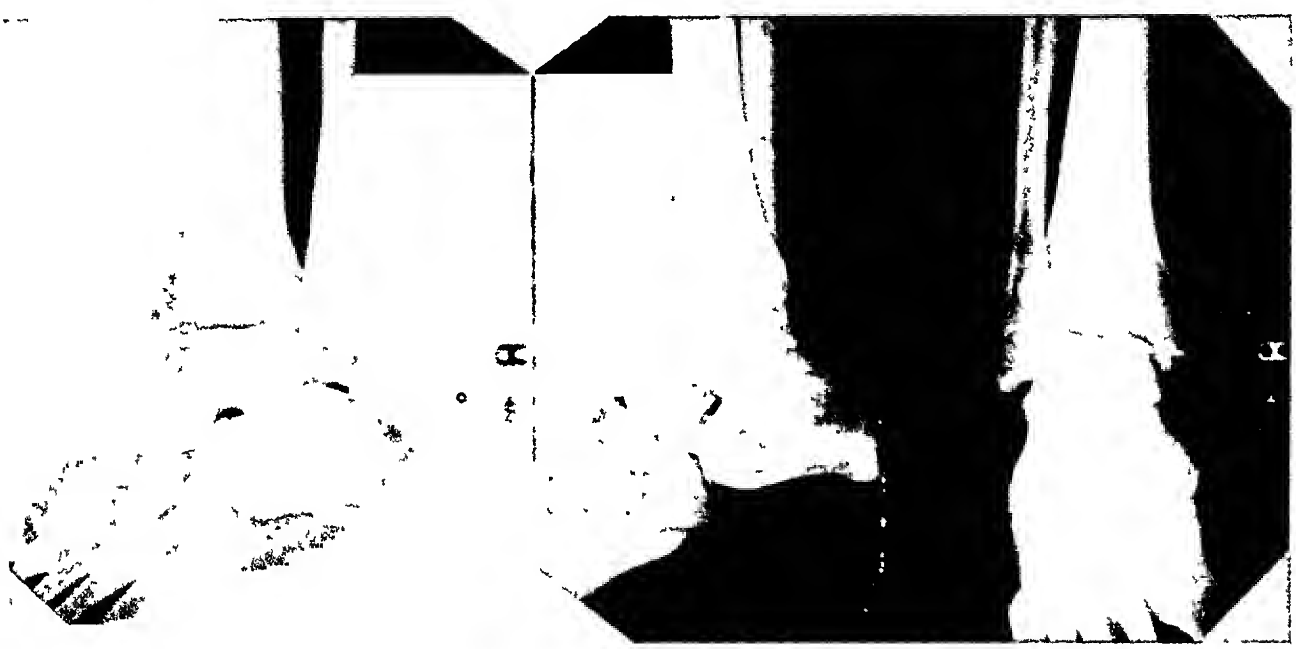

Fig. 1. The bony structures appear normal. No fracture can be seen. Clouding of the joint posteriorly exists with encroachment on the supracalcaneal triangle.

The series of cases observed at this station hospital are 4 in number and present similar findings clinically and roentgenographically. A single case report is submitted.

CASE REPORT

The patient, a white soldier, aged twenty-two, on January 12, 1944, was wrestling with another soldier and twisted his right ankle. At this time, he experienced considerable pain with swelling of the ankle soon following. He had difficulty in walking, with limited mobility of the

result of his poor response to this therapy, a recheck roentgenogram was taken on February 23, 1944. The roentgen report indicated "a linear film-like calcification between the fibula and the tibia apparently in the interosseous membrane. The deposits seemed to fade into the periosteum of the tibia about 3 inches above the ankle mortice. A crescent-shaped calcification along the posterior malleolus of the tibia could be seen and was not attached to the bone" (Fig. 2).

The soldier was then recommended for less arduous duty and physiotherapy was initiated. His symptoms improved within a period of two to three weeks with an abatement of the pain, and he carried out minor duties (clerical) successfully. Another roentgenogram was taken on May 10, 1944, which showed "the posterior deposit now to be of bony character and fused to the tibia. The interosseous calcified deposits remained the same" (Fig. 3). Clinically, the full range of motion of the joint had not returned; there was a limitation of eversion and dorsiflexion, and slight discomfort was still noted.

TREATMENT AND PROGNOSIS

The more conservative measures of immobilization and physiotherapy are logically the methods of choice. In the individual having moderately severe symptoms, bed rest with elevation of the extremity slightly above the level of the hip, and ice packs applied locally acting as mild anesthesia, tend to control the pain and discomfort. Salicylates with small doses of codeine may occasionally be needed. The milder cases are sent back to limited duty with a desk job prescribed as well as a request that the patient be exempt from physical training, marching formations, and duties requiring standing for any length of time. Diathermy is administered frequently with considerable amelioration of the physical symptoms.

If pain persists in the joint after conservative therapy, additional measures may be required. Injection of an anesthetic into the joint can be carried out as the results obtained by Leriche[18] in sprained ankles are unusually good following injection of an anesthetic into the traumatized tissues on the basis of his conception of sprain as an injury of the intraligamentous nervous system. His contention is that pain is due to contractures and that early injection into the periarticular structures is necessary. Unquestionably, there is a definite therapeutic value in this procedure but one must not forget the fact that some danger is connected with this method and an infection can be incurred.

Several men[16,17,23] have attempted surgical treatment of the condition in the knee which has been followed by a recurrence of the calcification. They strongly advocate allowing the lesion to become stabile before any surgical intervention is instituted. This seems reasonable in view of the similarity to myositis ossificans.

Radiation therapy has been used by Bellucci[2] with favorable results in respect to involvement of the knee. Other investigators are more conservative in acknowledging the use of irradiation in conditions similar to this one. Its use would seem most advisable in recent lesions of the evolutive type. The more mature calcification would tend to show less regression and dissolution of the deposits. Probably pain and muscle spasm may be influenced and benefited by irradiation based on the theories offered and discussed by Desjardins.[5] While we have not the therapy equipment at our hospital to adequately and properly irradiate these cases, irradiation undeniably has merit in conservative therapy.

The prognosis of disability of the ankle joint depends on the type and extent of the injury. In this condition, our cases have shown a partial disability of fairly long duration with a limitation of the functional capacity of the individual. An average of 15 per cent restriction of motion exists over a period of several months. The pain usually lessens during this time; whether this is due to improvement in the condition or an elevation of the pain threshold in the individual cannot be definitely ascertained. It is likely that the maturity of the lesion as well as disappearance of the edema about the ankle contributes to the diminution of

the pain factor. Full function is not entirely regained, and some clinical manifestation of disability remains. The calcifications persist and undergo either individual maturity or fusion. Spontaneous regression may occur but this has not as yet been seen in any of our cases.

I wish to thank Captain I.C. Winter, Captain J. J. Haggerty and Captain W. G. Hansen for their coöperation and suggestions in the preparation of this paper. The Army Air Forces Training Command deserves credit for the prints of the illustrations.

REFERENCES

1. Barr, D. P. Pathological calcification. *Physiol. Rev.*, 1932, *12*, 593–624.
2. Bellucci. Cited by Kulowski.[17]
3. Brailsford, J. F. The Radiology of Bones and Joints. J. & A. Churchill, Ltd., London, 1934, pp. 114, 136.
4. Burge, W. E., and others. Mechanism of pathologic calcification. *Arch. Path.*, 1935, *20*, 690–696.
5. Desjardins, A. U. Action of roentgen rays on inflammatory conditions. *Radiology*, 1942, *38*, 274–280. Also, Analgesic property of roentgen rays. *Radiology*, 1927, *8*, 317–324.

5a. Editorial. Pellegrini-Stieda's disease. Am. J. Roentgenol. & Rad. Therapy, 1932, *28*, 97.

6. Epstein, N. N., Paul, S. B., Rusk, G. Y., and Levin, E. A. Calcification of skin and subcutaneous tissues (calcinosis). *Arch. Dermat. & Syph.*, 1933, *28*, 510–520.
7. Ewing, James. Neoplastic Diseases. Fourth edition. W. B. Saunders Co., Philadelphia, 1940, p. 222.
8. Ferguson, A. B. Roentgen Diagnosis of the Extremities and Spine. Ann. Roentgenol., Vol. 17, Paul B. Hoeber, Inc., New York, 1941, p. 30.
9. Finder, J. G. Calcinosis cutis with heterotopic bone formation. *Illinois Med. J.*, 1937, *71*, 219–224.
10. Freund. Cited by Finder.[9]
11. Geschickter, C. F., and Copeland, M. M. Tumors of Bone. Revised edition. American Journal of Cancer, New York, 1936, pp. 785–786.
12. Ghormley, R. K. Multiple calcified bursae and calcified cysts in the soft tissues. *Tr. West. Surg. Ass.* (1941), 1942, *51*, 292–309.
13. Hitchcock, H. H. Calcium deposits about joints. *West. J. Surg.*, 1937, *45*, 353–361.
14. Klotz, O. Studies upon calcareous degeneration. 1. The process of pathological calcification. *J. Exper. Med.*, 1905, *7*, 633–675.
15. Köhler, Alban. Röntgenology. Second English edition. William Wood & Co., Baltimore, 1935, pp. 189–190.
16. Kulowski, J. Pellegrini-Stieda's disease. *J. Am. M. Ass.*, 1933, *100*, 1014–1017.
17. Kulowski, J. Post-traumatic para-articular ossification of the knee joint (Pellegrini-Stieda's disease). Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 392–404.
18. Leriche. Cited by Kulowski.[17]
19. Lewin, Philip. The Foot and Ankle. Second edition. Lea & Febiger, Philadelphia, 1941.
20. Oxford, T. M. Pellegrini-Stieda's disease. *Am. J. Surg.*, 1935, *27*, 543–544.
21. Pellegrini. Cited by Kulowski.[17]
22. Petrignani. Cited by Kulowski.[17]
23. Riebel, F. A., and Riebel, J. A. Pellegrini-Stieda's disease. *Am. J. Surg.*, 1934, *24*, 181–182.
24. Stieda. Cited by Kulowski.[17]
25. Stein, G. H., Gladstone, N. H., and Lowry, F. C. Pellegrini-Stieda syndrome. *Mil. Surgeon*, 1943, *93*, 167–172.

DISCUSSION OF PAPERS BY DRS. LEWIS, GERSHON-COHEN, AND PIATT

Dr. Lawrence Reynolds, Detroit, Michigan. I wish to compliment Dr. Gershon-Cohen for a splendid presentation of an important subject. Since 1937 we have been making this type of examination both at our office and at Harper Hospital, and we have examined a number of cases. Over one hundred cases have been operated upon as a result of this type of examination and in two of those cases we had missed the lesion.

The technique is an excellent one for the examination of injuries to the knee joint in that it is not a difficult one, but it does require a very special, meticulous care in the examination of these patients. As Dr. Gershon-Cohen does, we examine both knees in the anteroposterior projection and also in the lateral projection, with particular attention to the soft tissue detail, which he has so nicely shown in his roentgenograms. We examine these three films before we "stretch the knee" because we want to be sure there is no contraindication to the stretching of the knee joint. Our method of examination is essentially the same as Dr. Gershon-Cohen's. Our roentgenograms at the time of stretching the knee are made either in the anteroposterior or the posteroanterior projection.

We also have had two or three cases where there appeared to be a slight regeneration of the cartilage after it had been removed, but

appearances similar to regeneration will be shown on the roentgenogram taken during the stretching of the knee joint.

We have found that in cases where there was injury to the cartilage, there is a small amount of sclerosis along the margin of the internal tibial tuberosity. This may be very slight and requires careful examination. If a magnifying glass is used in the study of the anteroposterior view, a slight sclerosis will be seen which gives some clue and that and a very small amount of effusion in the suprapatellar bursa of the injured knee, as well as an inability to demonstrate the internal semilunar cartilage, are the criteria for making the diagnosis. We try to be very careful in this sort of examination because unless the technique is carried out properly, one may be misled in the interpretation of the roentgenograms.

We have not been able to show the external semilunar cartilage with any degree of satisfaction and I am pleased to know that Dr. Gershon-Cohen has been able to show it in about 20 per cent of his cases.

Of course we never use this type of examination in acutely injured knees. It is used in those cases in which the patient gives a long history of disturbance in the knee joint. However, with this method of examination I think one can demonstrate very definitely whether or not there is a derangement of the cartilage.

Dr. Ralph S. Bromer, Bryn Mawr, Penna. Captain Piatt is to be commended for bringing to the attention of roentgenologists this lesion of the ankle joint. He mentioned two types of the lesion, the evolutive and the later type in which the fuzzy, variegated appearance of the calcification changes to a stabilized type which is a well defined, sharply outlined, calcified shadow. Pellegrini, in describing the lesion in the knee joint, attempted to go somewhat further and explain the characteristics of the lesion according to the nature of the injury. Thus, those secondary to sprain were small and presented regular margins, while those secondary to or around a hematoma were more squat and globular and sometimes irregular in outline. He also stated that in the knee joint when the lesion occurred after attempts at mobilizing a partially ankylosed joint the calcified areas were quite large, voluminous and irregular. After sprains of the knee joint the lesion was often longitudinal, after contusion it was often transverse, and after both sprain and contusion combined it was expansile in both directions. I think it will be interesting to note whether such distinctions can be made in the ankle joint.

The medicolegal aspect of this lesion is important and, again to quote Pellegrini, his rules for indemnification of cases in Italy may be useful. He stated that (1) no indemnity should be granted in cases where ossifications are slight and when no atrophy of the joint or any other joint changes are present; (2) minimal indemnity could be granted when atrophy or joint changes are slight or when the lesions are conspicuous in the roentgenogram; (3) when functional limitation is severe, indemnity should be higher but emphasis must be laid on the fact that only a small part of the disability is usually due to the ossifications themselves.

In regard to the case shown by Captain Piatt it would seem that the location and its close relation to the interosseous membrane would be an argument in favor of the periosteal tear theory in the production of the lesion.

Dr. Lewis is to be commended for drawing our attention again to the work of Phemister on the differential diagnosis of pyogenic and tuberculous arthritis. There is one point that is worthy of mention in regard to the long preservation of the joint space in tuberculous arthritis. If, in cases of pyogenic arthritis, the infection begins in an extra-articular location near the capsule of the joint, the joint cleft may be preserved until the infection finally ruptures into the joint. This may be confusing in that at first it may resemble the picture of a tuberculous arthritis. Once the rupture has occurred the cleft disappears as described by Dr. Lewis in pyogenic infection.

Dr. Ross Golden, New York. I have long been an admirer of Dr. Lewis' skill in the interpretation of soft tissue shadows about joints, particularly about the knee. It seems to me that we have not yet devised the best technique for the knee joint shadows. If we use a technique which shows the soft tissues, we are likely not to get the detail of the center of the bone. On the other hand, if we show the center of the bone, we are likely to obliterate the soft tissues. We have been trying in some cases the taking of roentgenograms with a heavy filter, 0.1 mm. of copper, using about 75 kv. If one is careful not to overexpose, one can get bone structure and can show, in some cases beautifully, the soft tissue structure, the tendons, etc., around the knee joint.

I do not think that is as yet the ideal technique. Possibly a combination of exposures on the same immobilized joint, using a heavy filter and then taking the filter out for perhaps 10 to 25 per cent of the exposure and using an unfiltered beam, would be still better. We need to do a little more experimenting with technique to show the knee better.

I have also been admiring Dr. Gershon-Cohen's work with these meniscus and other knee injuries, and I would like to ask him whether he believes we should use that tangential view of the patella in all cases of routine examination of the knee, or whether he feels it is necessary only in the injured cases.

Dr. Gershon-Cohen (closing). I wish to thank Dr. Reynolds and Dr. Golden for their very kind remarks.

Any technique that can be used to bring out the various soft structures, such as the method advocated by Dr. Golden, is highly desirable; but I think that, finally, more can be accomplished by making regular exposures without special techniques for different tissues and resorting instead to the use of special viewing apparatus for obtaining all the information the roentgenogram has to offer.

So far as the tangential view of the patella is concerned, I suppose the question resolves itself into one of economics and individual preference. If each patient could be examined clinically by the roentgenologist, perhaps it might be possible to exclude those cases in which this view could be omitted. Nevertheless, if the tangential view of the patella is not taken routinely, it is surprising how much valuable diagnostic information is lost.

TRANSITIONAL EPITHELIAL CELL CARCINOMA OF THE NASOPHARYNX*

By J. E. WHITELEATHER, M.D.
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Attention is usually directed to the nasopharynx by angina, epistaxis, dysphonia, dysphagia, nasal or pharyngeal obstruction and cervical adenopathy. Such attention is not usually given this region when the presenting symptoms are a slight alteration in hearing, tinnitus, pain in the maxilla or mandible and symptoms referable to the various cranial nerves. That these latter signs and symptoms should indicate a most painstaking search of the nasopharynx for malignant lesions is not a matter of common knowledge, in spite of numerous expositions on the subject in the last thirty years.

Nasopharyngeal tumors have been given careful consideration by otolaryngologists, roentgenologists, and pathologists, yet, unfortunately, there are very few patients whose pathological condition is diagnosed before an advanced stage is reached.

Transitional epithelial cell carcinoma has been, in our experience, the most common variety of tumor found in the nasopharynx. It comprises over two-thirds of the nasopharyngeal growths observed in the Department of Radiology of the Baptist Memorial Hospital. The tumor is an unusually cellular growth, which invades and infiltrates surrounding structures and metastasizes rapidly. It is composed of extremely undifferentiated, anaplastic cells and its clinical course is very characteristic, usually rapidly fatal.

Tumors, other than transitional cell, have been excluded from this study; all cases have exhibited typical clinical symptoms and the reports of the biopsies have been positive.

These tumors are considered to be rare, yet 16 have been observed and treated in a period of five years, from July, 1937, to July, 1942; also, at least sixty articles on the subject appear in the literature, some containing large series of case reports.

HISTORICAL

In 1903 Krompecher[10] described an undifferentiated tumor of the nasopharynx which he believed arose from the basal cell layer of the mucosa and named it basilioma. However, Trotter[22] was the first to point out the unusual clinical features of this disease in 1911. In his description of "Certain clinically obscure malignant tumors of the nasopharyngeal wall," he noted "the unusual difficulty in making this diagnosis," and the very important point that "diagnosis is entirely dependent upon the recognition of symptoms of infiltration of the nasopharyngeal wall, extension into the cranial cavity, involvement of the eustachian tube and early metastases to the glands of the neck."

In 1921 Reverchon and Coutard[18] reported from Regaud's Clinic a tumor which was highly radiosensitive and composed of anaplastic cells of epithelial origin intermixed in a syncytium with varied numbers of leukocytes. Because they believed that these cells arose from cells located around lymphoid tissue deposits in the pharynx and nasopharynx which resembled both epithelium and lymphoid cells, they called it lymphoepithelioma. In the same year Schmincke[20] described a tumor which differed slightly from the Regaud type in that the principal cells were scattered diffusely in a loose reticulum.

In 1921 Jacod[9] recognized the growth and wrote of it as "peritubular sarcoma." He believed that the intracranial extension took place by way of the bony part of the eustachian tube but was directed forward into the middle fossa by the denseness of the petrous bone.

* From the Department of Radiology, Baptist Memorial Hospital, Memphis, Tennessee.

In 1931 New[15] of the Mayo Clinic brought to the attention of American otolaryngologists the syndrome of malignant tumors in the nasopharynx.

Woltmann[24] analyzed the neurological findings in New's cases and isolated case reports collected from the literature the same year. In 1923 Crowe and Baylor[3] described the findings and results of surgical and radium therapy on a large number of cases of "sarcoma and carcinoma" of the nasopharynx, many of which would now be considered transitional cell carcinoma.

The term transitional cell epidermoid carcinoma was introduced by Quick and Cutler[17] in 1927. They were impressed by the lack of usual squamous cell features in the carcinomas and their high radiosensitivity. Hayes Martin[13] has written extensively on the therapeutic aspects of the disease.

PATHOLOGY

This neoplasm usually begins in the nasopharynx in or near the fossa of Rosenmüller, in the vault around the pharyngeal tonsils, on the lateral wall, the palatine tonsils, the lingual tonsils, the base of the tongue and rarely the hypopharynx. There have been cases described that were found in the ethmoid and maxillary sinuses, but it is questionable whether this was the primary focus. Secondary foci have been described by Gardham due to contact of polypoid nasopharyngeal growths.

Trotter divided his cases into two types: (1) those that were polypoid and extended into the nasopharynx, sometimes to such a degree as to obstruct the nares, displace the soft palate and produce symptoms of pharyngeal obstruction; (2) those in which this polypoid development was absent.

The second class of tumor is more common and much more difficult to diagnose. When observed in the nasopharynx the tumor is commonly small and may present only a slight flat nodule in the region of the eustachian tube or fossa of Rosenmüller. It may be slightly pink in color and appreciable only as a perceptible hardening in the wall of the pharynx. There may be slight ulceration, and if ulceration is present a yellowish mucoid membrane may obscure it. *A curious characteristic of the growth is its tendency to spread widely beneath the mucous membrane without causing ulceration.* This has been emphasized by Cappell[2] in his study of lymphoepithelioma. The neoplasm burrows beneath the mucous membrane invading the deeper tissues of the pharynx and extending through the basal foramina into the middle fossa of the skull. The muscles of the neck and face may also be infiltrated. The eustachian tube, quite early, may be compressed or completely blocked. Cases of mastoid destruction by extension through the eustachian tube have been described. Metastasis to the lymph nodes of the neck is a very early and common feature. Distant metastases often occur in the late stages of the disease.

The process usually extends into the skull by way of the floor of the middle fossa. It is probably prevented from extending dorsally into the cervical vertebrae and soft tissue by the dense pharyngeal aponeurosis. This structure may tend to direct it upward into the sphenoid and temporal bone. Most writers have believed that invasion of the cranium takes place through the basal foramina. Martin and Blady[14] indict the foramen lacerum and Jacod the eustachian canal and the petrotemporal suture. Some of our patients exhibited so much erosion of the greater sphenoid wing that it seemed probable that the invasion took place by invasion and infiltration of the bone itself. In some instances the foramina could be clearly defined in an area of partial destruction.

A recent autopsy, reported by Bach, Lederer and Palevsky,[1] included a description of the route of invasion. There was destruction of the petro-occipital suture, the foramen lacerum, the greater sphenoidal wing and the tip of the petrous pyramid. They believed the tumor grew by eroding and replacing the bone, having a special affinity for the marrow spaces.

Once in the cranial cavity, it burrows beneath the dura but seldom breaks through. It may extend along the cavernous sinus, destroy the clinoids and invade the orbit through the superior orbital fissure. It rarely enters the posterior fossa yet the petrous apex is often eroded and one of our cases showed destruction around the jugular foramen.

It is quite probable that most cranial nerve involvement occurs in the cavernous sinus and not necessarily in the basal foramina.* This is particularly true of the third, fourth, ophthalmic branch of the fifth, and the sixth nerves, since they course through the cavernous sinus to emerge through the superior orbital fissure and not through the floor of the middle fossa. Involvement of the abducens nerve, a common complication, would, then, usually indicate invasion of the cavernous sinus.

Involvement of practically all the cranial nerves has been reported. Those most commonly affected are the fifth, sixth, third and fourth as shown by reports in the literature. Involvement is progressively less on either side of these four nerves, in ascending or descending order.

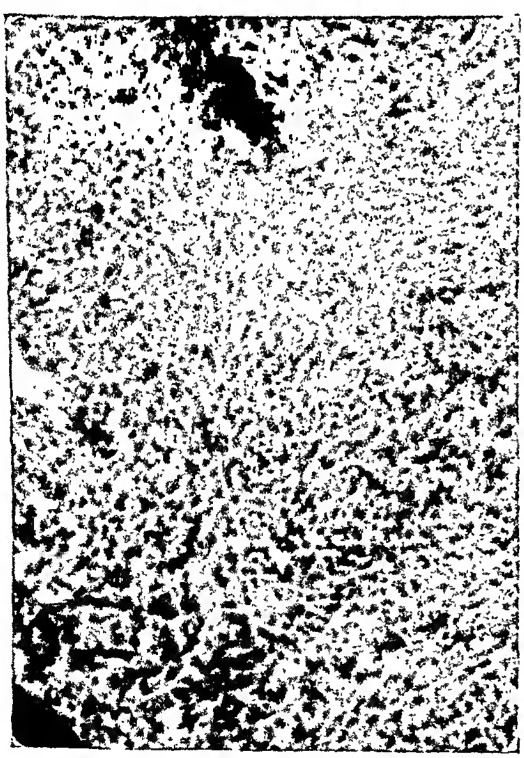

Fig. 1. Low power photomicrograph of typical section of transitional epithelial cell carcinoma.

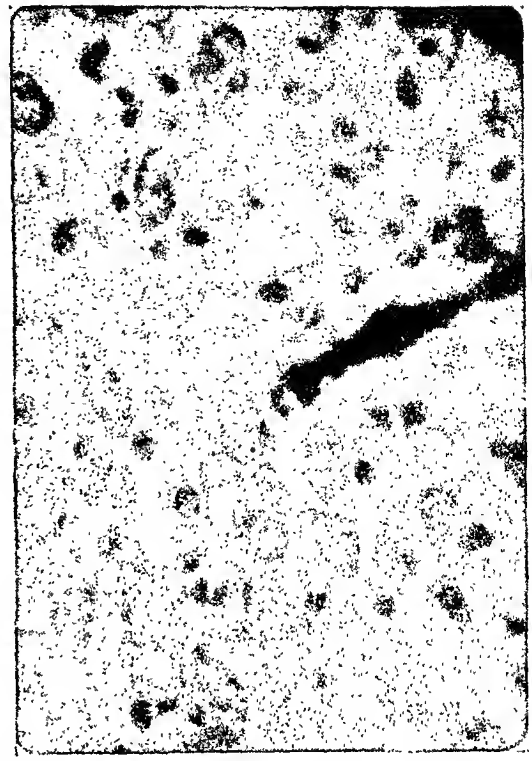

Fig. 2. High power magnification of same section.

MICROSCOPIC PATHOLOGY

It is not our intention to enter into a discussion of the cellular pathology and identification of the cell origin. There is considerable confusion in the literature and disagreement among pathologists as to the nomenclature and biologic nature of these tumors. Regaud, Schmincke, Cappell, and others, have described these lesions under the term lymphoepithelioma. Although some pathologists attempt to differentiate the Regaud, Schmincke and Ewing types, in America it has been the custom to group them under the term advanced by Quick and Cutler, and Ewing of "transitional epithelial cell carcinoma.

Salinger and Perelman[19] in an effort to simplify the nomenclature submitted a group of microscopic slides to three pathologists. Although there was a certain uniformity of opinion, some of the same sections were classified under lymphoepithelioma, transitional cell carcinoma and anaplastic epidermoid carcinoma. Thus, the exact terminology is often modified by personal opinion and experience.

* An article by Lenz[11] emphasizes this point.

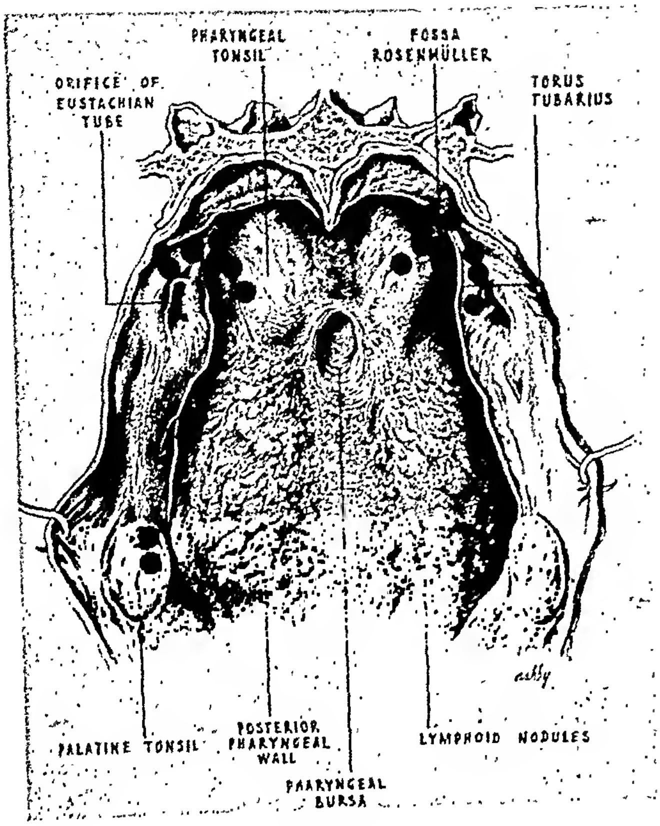

FIG. 3. Locations of pimary lesions in 15 cases.

Ewing[4,5,6] has pointed out the extreme difficulty in making a clear distinction between the anaplastic growths of this region. A recent careful study by Frank, Lev and Blahd[7] compares the different types of cells and, despite balanced objections, retains the term transitional cell carcinoma.

The fundamental cell in our series of cases was relatively large with indistinct cytoplasm. There was no intercellular bridging. The cells grew in a loose syncytium, in narrow columns which infiltrated the surrounding submucosal tissue, or in tightly packed sheets. Lymphocytic infiltration was either marked or clearly evident. The cell nuclei varied somewhat in size but were usually rather large and round, or oval with sharp nuclear membranes. They were moderately hyperchromatic. Nucleoli were numerous and stained deeply. The cytoplasm was indistinct, moderately basophilic and varied considerably in amount in different slides. The cells seemed in several instances almost sarcomatous in appearance, yet in others bore a resemblance to reticulum cells. The number of mitotic figures was high. There was little difference in the appearance of the section regardless of whether taken from primary lesions located in the fossa of Rosenmüller, the faucial tonsil or near the pharyngeal tonsils. Those from the large polypoid tumors were similar to those obtained in the flat infiltrative lesions. Of great interest was one section, taken from a recurrent polyp several months after irradiation, which showed cells that were definitely more adult and differentiated in appearance than were the original sections, before irradiation.

CLINICAL FINDINGS

Even when the disease had reached an advanced state the diagnosis was often difficult to make. Unless the tumor, itself, had reached large proportions, the primary lesion was easily overlooked. On occasions, when all clinical signs pointed to the presence of this disease, repeated nasopharyngeal examinations were necessary before the lesion was located. Although it can usually be seen with a mirror, it has, in several instances, been found only with a

FIG. 4. Polypoid growth arising in vault of nasopharynx (retouched).

nasopharyngoscope. The latter instrument is also valuable in observing the effect of irradiation on the lesion.

The symptoms were variable and often vague and confusing. They resembled, as Woltmann puts it, "a melange of head symptoms." Patients complained of "double vision," "sinus aches," "severe toothache," "facial neuralgia," "deafness," "roaring or clicking" in one ear, and difficulty in breathing through the nose. There was blindness in one eye, ptosis, internal strabismus, dilatation of the pupil, severe pain in the face and jaw, difficulty in swallowing, trismus, deviation of the uvula or tongue, and other findings indicative of cranial nerve involvement.

Many of the patients gave a history of fruitless operations. Two patients had had mastoidectomies, 1 repeated sinus operations, and 8 repeated insufflations of the eustachian tube. Three had had paracenteses, 5, dental extractions, 1 an ethmoidectomy for proptosis, actually due to invasion of the orbit. New commented upon the large number of operations in his series.

A unilateral compression of the eustachian tube occurred early in the disease in 12 instances. This is usually a minor symptom and is described as a clicking sound or a roaring and may be associated with a serous discharge. A careful interrogation is usually necessary to obtain this history. Most patients will suffer a definite diminution of hearing in one ear by the time they come for treatment. One case, which had been diagnosed as primary lymphosarcoma of the cervical lymph nodes, while under radiation treatment was observed to be deaf in one ear and an examination of the nasopharynx revealed the primary lesion. Since it was so commonly associated with rhinitis and pharyngitis, little attention was paid to its presence except for repeated attempts to relieve it by insufflation of the tube or paracentesis. Early involvement of the tube may not occur if the primary lesion is located elsewhere than the peritubal region, but this was the earliest and most common symptom in this series. It usually preceded by many months the onset of cranial nerve involvement.

Fig. 5. Early cervical metastases in same patient.

Fig. 6. Same case, four weeks after irradiation.

Cervical adenopathy was the next most common finding. In many instances, it was the first sign of disease. Various writers

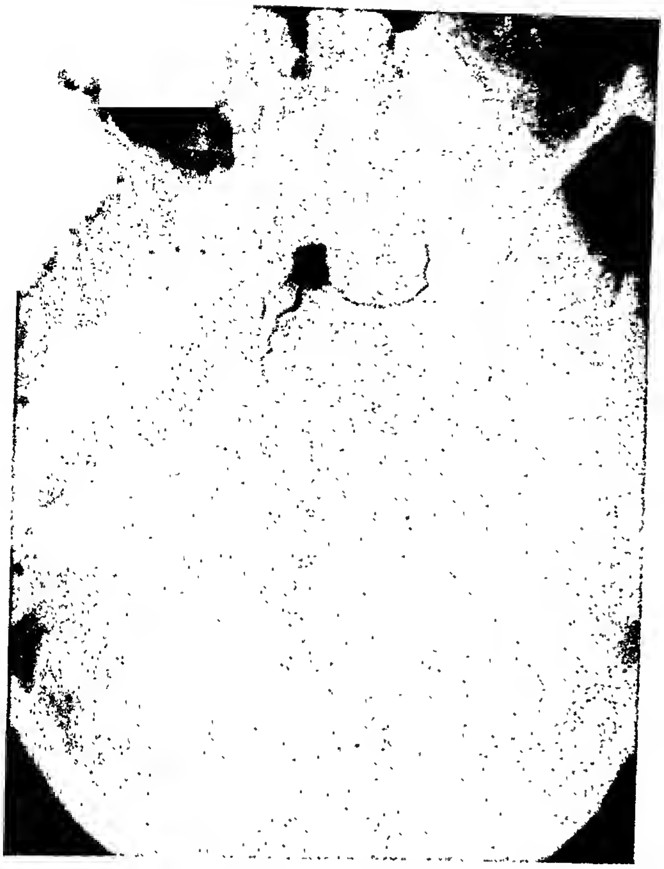

Fig. 7. Mentovertex view before irradiation.

have found adenopathy present in as high as 80 per cent of their cases. The nodes may vary considerably in size and are often painful. It is difficult to decide whether the pain arises in the nodes themselves or is due to involvement of the upper cervical nerves and branches of the fifth cranial nerve. Involvement is usually bilateral and since the nodes are usually smooth, firm, discrete and not fixed to the skin, the diagnosis of Hodgkin's disease or primary lymphosarcoma is often made. Metastatic cervical nodes were the second most frequent finding in our cases, being present in 9 on admission and eventually in 11 patients. The earliest to appear was the lateral retropharyngeal node on the affected side. This could be palpated just behind the angle of the jaw, and displaced the lobe of the ear outward and backward. Later, the deep cervical chain, lying along the anterior border of the sternocleidomastoid muscle became involved. Eventually nodes appeared in the posterior triangle and supraclavicular space.

There was cranial nerve involvement in 9 cases. This was unassociated with any other signs or symptoms (except those referable to the euastachian tube) in only 4 cases. It is interesting to note that these 4 were patients of a neurosurgeon, who suspected the presence of a nasopharyngeal lesion from the pattern of cranial nerve pathology. Roentgenography of the skull demonstrated invasion of the middle fossa before the primary lesion was discovered. All 4 cases had had previous nasopharyngeal examinations and 2 extensive mastoid and sinus surgery.

The sixth nerve is the one reported most often involved by New, Woltmann, and Martin and Blady,[14] C. L. Martin,[12] and others, but only 5 of our cases exhibited lateral rectus paralysis. The presence of intransigent pain over the distribution of the second and third divisions of the fifth in 8 cases and of the first division in 3 of the 8 made this nerve the most commonly affected in this series.

Epistaxis occurred in 4 cases and in 2 was the only symptom. One of these ex-

Fig. 8. Same patient as in Figure 7, fourteen days later.

hibited a lesion of the faucial tonsil which was easily found. The other a small flat nodule in the fossa of Rosenmüller. Both were early lesions with no invasion or metastasis and are the only 2 in the series living and free of all evidence of active disease.

Nasal obstruction was present in 4 cases. In 1 case a polypoid growth had extended forward from the epipharynx into the nares and was easily visualized through a nasal speculum. Only 1 case showed infiltration of the soft palate and paterygoid muscles.

Six cases eventually suffered invasion of the orbit with proptosis, which was always a late development.

Distant metastases complicated 4 cases late in the course of the disease. Two were in the upper dorsal spine and the other in the long bones of the legs. Occurrence of mediastinal and pulmonary metastases, as described by C. L. Martin[12], was not observed.

The age distribution was rather unusual, although it corresponds, in general, with that given by other authors. Seven patients were under twenty years of age and 9 were over twenty. Of these, 7 were fifty or over. The youngest case was aged ten and the oldest fifty-seven. Two patients were brothers, ten and fifteen years old respectively. When receiving the report of the death of the eldest we also heard that a small child in the family was dying of enlarged glands in the neck.

The distribution between the sexes was almost even, 9 male and 7 female. Most reports show a preponderance of males. Five of the 9 male patients were under twenty.

Table I

Case No.	Sex	Age	Duration of Symptoms before Diagnosis	Location of Metastases	Roentgen Dose to Primary Lesion	Survival Period
1	M	54	16 mo.	Cervical; cranial	2100 r	Died in 15 mo.
2	M	10	6 mo.	Cervical	2100 r	Died in 6 mo.
3	M	18	4 mo.	Cervical	2350 r	Died in 6 mo.
4	M	19	2 mo.	Cranial	2700 r	Died in 6 mo.
5	F	55	1 mo.	None	3500 r	Free of disease
6	M	18	4 mo.	None	2390 r	Free of disease
7	F	52	16 mo.	Cervical	2600 r	Died in 24 mo.
8	F	48	3 mo.	Cervical	2650 r	Died in 7 mo.
9	F	15	4 mo.	Cranial; cervical	3200 r	Died in 12 mo.
10	F	17	6 mo.	Cranial	1350 r incomplete	Died in 7 mo.
11	M	20	2 mo.	Cervical; cranial; spine	Palliation	Died in 5 mo.
12	F	34	14 mo.	Cervical	3200 r	Free of disease
13	M	42	24 mo.	Cervical	1800 r	Died in 7 mo.
14	M	55	22 mo.	Cervical	2000 r	Living with disease
15	F	50	6 mo.	Cranial	Treatment finished elsewhere	Living with disease
16	M	58	10 mo.	Cervical; cranial	2100 r	Living with disease

The duration of symptoms, before diagnosis, was quite variable, often surprisingly long. The shortest symptom period was one month (epistaxis); the longest was two years (tinnitus), with most cases from four months to two years in duration.

The primary lesion was in or adjacent to the fossa of Rosenmüller in 10 instances, the palatine tonsil in 3, the pharyngeal tonsil in 2 and unknown in 1 case. The primary location did not seem to influence the cell type, the degree of malignancy, the course of the disease or the radiosensitivity of the tumor.

Roentgenographic studies have been

helpful in establishing the diagnosis and evaluating the extent of the process. Lateral and mentovertex views of the nasopharynx and oropharynx often showed luminal defects on the posterior and lateral walls. Even when the lesion, as observed on direct examination, was small, it was surprising how thick the posterior retropharyngeal wall was. Since this usually regressed under treatment it is assumed that it is a measure of the amount of malignant infiltration. In several, in which such thickening was present, there was but a small break in the mucosa and the first several biopsies were negative. This emphasizes Martin and Blady's statement that the biopsies must be taken deeply, and probably explains why surface biopsies were often negative. It also probably explains the apparent discrepancy between the size of the visible primary lesions and the remarkable extent of the disease process.

Views of the base of the skull were not routinely taken on the first few cases, but were on the later ones. Mentovertex or base views are difficult to interpret as the foramina are not always symmetrical and the amount of cartilage is variable. It has been found necessary to make several views at slightly different angles to visualize all the foramina to best advantage. Erosion was found most frequently around the foramen ovale, foramen lacerum, the body of the lesser wing of the sphenoid, and the petrous apex. One case showed definite erosion of the jugular foramen. Roentgenograms should always be made before starting treatment as the size and position of fields may be determined by the findings. They also provide an excellent record of the effect of treatment.

Table II

Case No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Primary Location*	T	P.T.	F.R.	F.R.	T	F.R.	F.R.	F.R.	P.T.	F.R.	?	F.R.	F.R.	F.R.	F.R.	F.R.	2 T 2 P.T. 11 F.R.
Eustachian Tube Involvement	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	12 yes
Nerves Involved	II III	No	No	III IV V VI	No	No	V	V	V VI	IV V VI VII IX	V VI	No	No	III V VI IX Symp.	V C-1 C-2	No	9
Adenopathy	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	10 yes
Angina	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No	Yes	No	Yes	No	No	8 Yes
Nasal Obstruction	No	No	No	No	No	Yes	No	Yes	Yes	No	No	No	No	No	No	Yes	4 yes
Invasion of Orbit	Yes	No	No	Yes	No	No	Yes	No	Yes	No	Yes	No	No	No	No	Yes	6 yes
Epistaxis	No	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	No	No	No	3 yes
Distant Metastases	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	No	No	No	4 yes
Previous Operation	No	1	No	2	No	No	1	1	No	1	3	1	No	No	2	2	9

* *T = Faucial tonsil P.T. = Palatine tonsil F.R. = Fossa of Rosenmüller*

THERAPY

Although Regaud in his original description of lymphoepithelioma emphasized its sensitivity to irradiation, total reliance on this method of therapy was slowly accepted by the medical profession in general. As late as 1929 Gardham[8] described a surgical exposure to permit direct attack on the lesion; he along with earlier writers has expressed disappointment in the results and prognosis. However, Quick and Cutler, C. L. Martin, H. E. Martin and Blady and

others have emphasized the extreme radiosensitivity of the malignant process and have shown some encouraging results. The use of high voltage roentgen radiation alone or combined with radium or radon has become the accepted method of treatment.

The high degree of malignancy and infiltrative character of the disease plus the location of the primary lesion make adequate surgery an impossibility. It is quite true that results are still not wholly satisfactory, but if the disease is diagnosed early enough so that irradiation can be given before invasion or metastases have taken place, the possibility of eradication of the disease is anything but hopeless.

It is probably superfluous to state that each patient presents a specific problem and that no routine method of treatment can apply to all. It is our general procedure to examine each patient with the otorhinolaryngologist in order to observe the primary lesion and the extent of infiltration in the nasopharynx. Frozen and permanent paraffin sections are studied with the

Fig. 9. Destruction of left petrous apex and both greater sphenoid wings.

Fig. 10. Abducens paralysis (base view Fig. 9).

pathologist to determine cell morphology. The extent and location of neurological involvement, if present, is charted by the neurosurgeon. The size and location of other metastatic lesions must also be taken into consideration. If cervical nodes are so located as to be included in the beam directed at the nasopharynx, this field may be larger than normally used. If the enlarged nodes are in the lower cervical region or supraclavicular space, separate fields are required. On some occasions it will be necessary to direct treatment first to some lesion other than the nasopharynx, if it is producing very distressing symptoms. After a sufficient dose is administered to this area the primary focus can then be attacked.

It has been possible to treat the primary lesion first in most of these cases. We have usually adhered to the principle of using moderately small portals accurately directed. It is believed that the use of a field approximately 7 cm. in diameter will cover the primary lesion in the nasopharynx including the usual area of extension in the base of the middle fossa. The smaller fields permit a slightly greater dosage with less skin damage and pharyngeal discomfort.

Fig. 11. Bilateral invasion of lesser sphenoid wings.

The depth dose is slightly less than with larger fields but the increased dosage permitted will make up this deficiency. It is also possible to add several more fields without danger of substantial overlapping.

Occasionally when the preauricular or upper deep cervical nodes are large, a circular field 10 cm. diameter is used directed in the coronal plane through each temporal area. When the total dose to each field approaches 1,500 to 2,000 roentgens (in air) (2,000 to 2,600 with backscatter) the field is narrowed to 7 cm. and the dosage increased to 3,000 to 3,500 r (in air) (4,000 to 4,500 with backscatter) to each field. On some occasions when the primary lesion was small and it was not believed that diffuse infiltration of the nasopharyngeal wall had occurred a field 5 cm. in diameter was used. As our experience with the disease increased two additional fields were added, a circular beam 5 cm. in diameter was directed through the cheek on either side of the nose so directed as to cross-fire on the lesion. When this field was used, it was necessary to protect the cornea with a lead shield. A sheet of soft lead was inserted in the mouth and molded around the teeth, similar to a dental mold, to protect the tongue and lower teeth. The patients soon learned to fit it in place before each treatment. The paranasal field also gave an additional amount of irradiation to the invaded area in the base of the skull. In 5 instances in which there was exophthalmos and unquestionable invasion of the superior orbital fissure, additional fields were located both above and lateral to the orbit in order to include the floor of the anterior fossa.

A potential of 220 kv. (peak) at 20 ma. and 60 cm. target-skin distance has been used on all patients. The filtration has been varied from 0.5 mm. Cu and 1 mm. Al added to 2 mm. Cu or a No. 2 Thoraeus filter added. The majority, however, have been treated with 0.5 mm. Cu and 1 mm. Al which gives a half-value layer of 0.9 mm. Cu. We have been unable to observe any difference in results following the use of heavy filtration. It is probable that a slightly higher total dosage could have been

Fig. 12. Small nodular lesion of the left fossa of Rosenmüller. Note amount of infiltration in retropharyngeal wall.

administered with a little less skin reaction but the treatment of a large number of patients daily has prevented the use of prolonged treatment periods. The 20 kv. addition and 60 cm. target-skin distance almost compensates for the slightly greater depth dose obtained with heavier filter. The daily dose has varied slightly, depending upon the size and number of fields used, the general condition of the patient and his reaction to the treatment. It was not always possible to treat each patient as we might have desired or as our experience indicated.

It was believed that due to the anaplastic nature of the tumor cells a high total dose should be attained quickly and the majority of patients were treated with a daily increment of 300 r (in air) (390 r with backscatter). Yet it was observed that our best results were obtained in 2 cases with a dose of 200 r (in air) (260 r with backscatter) to one area daily. This prolonged the treatment period to the primary lesion to thirty or forty days and in neither case was there any evidence of extension or metastasis.

Cervical metastases were usually treated through a separate field, with a daily dosage of 300 r (in air) and a total dosage of from 2,000 to 3,000 r. The nodes ordinarily began to shrink and pain began to subside after the first several days of treatment. In most cases the dosage was sufficient to reduce the node considerably or accomplish a complete regression. Several of the patients experienced a recurrence of nodes which might have been prevented with a larger dose. Recurrent nodes failed to respond as satisfactorily as on the first series of treatments. When involvement of the cranial nerves had occurred it was possible to produce a temporary palliation of pain but no case in which a complete paralysis had been initially observed ever obtained a return of function. Several times paralyses occurred some time after the series of treatments, even though the probable areas of intracranial extension had been irradiated.

An estimate of tumor dosage has been given for each case. However, frequent observations of the effects of irradiation and the experience of the radiation therapist in treating these lesions is probably more important. Mathematical estimates of tumor dosage are apt to be erroneous since they are estimated at one or two levels and so infiltrative a tumor may lie at various depths. It was also observed that the tumor varies considerably as some react well to small doses while others will recur after large doses.

Fig. 13. Distribution of radon seeds around right palatine tonsil.

In some of the cases, external irradiation was not carried to as high a dosage as was considered possible because intracavitary treatment supplemented the external treatment. When the primary site was accessible, radon seeds were implanted by the otolaryngologist. Usually ten to fifteen 1 millicurie seeds gave a sufficiently even dosage to the focus. When the lesion was located in a less accessible area of the nasopharynx, a radium capsule was held against it by a Martin-Blady applicator or similar apparatus. With this the filtration was 1.3 mm. platinum plus variable amounts of

rubber. The dose ranged from 10 to 15 erythema doses per unit area.

Intracavitary irradiation was not given to those cases in which considerable infiltration of the nasopharynx was present. It can only be of value when the primary lesion is unquestionably limited in area.

Cervical adenopathy was treated with external irradiation only. It was not believed that cervical resection was advisable even though there was no tendency on the part of the metastases to rupture the nodal capsule.

One patient had had a block resection of the anterior deep cervical chain before the diagnosis was established. When first seen there was adenopathy on the opposite side of the neck. Both sides were irradiated and the only recurrence noted was in an area other than the resected region.

The question of giving so-called prophylactic irradiation when no cervical adenopathy is present is a difficult decision to make. Since cervical metastases develop so frequently it would seem wise to irradiate the neck routinely, particularly since the tumor is composed of cells so radiosensitive that the objection to such prophylactic irradiation in the more differentiated tumor processes may not hold. The possibility of administering a cancericidal dose is better than in the less sensitive tumors.

However, it was believed that the patients who showed no evidence of metastases should not be subjected to heavy irradiation and it was not believed worth while to administer less than a cancericidal dose. The 3 patients who are living and free from disease did not receive treatment to the neck. The other 6 cases which did not present cervical adenopathy on admission received treatment to these nodes only when they appeared. If enlarged nodes appear after a considerable period following irradiation of the primary focus it indicates that the primary focus is still active and should have been treated more aggressively.

One of the most distressing symptoms is the severe anginal pain experienced over the distribution of the branches of the fifth, ninth and the upper cervical nerves. It has not been possible to effect more than a temporary palliation by irradiation. Various measures have been undertaken in an effort to relieve this pain, namely cocaine, saline and alcohol injections. Drs. R. E. Semmes, J. F. Murphey and Antonio Grino have used the procedure of tractotomy as introduced by Sjöqvist[21] and modified by Olivecrona[16] and Weinberger and Grant.[23] This operation consists of surgical transection of the descending tract of the trigeminal nerve in the medulla. It is also possible to section the ninth nerve and the first and second cervical roots at the same operation. The procedure is carried out under local anesthesia. A straight incision is made in the low occipital region. The fourth ventricle is exposed by hemilaminectomy of the first cervical vertebrae and removal of a part of the posterior margin of the foramen magnum on the affected side. The operation involves little risk in the hands of an expert neurosurgeon and has been successfully carried out on 3 patients with excellent results. It is much preferable to division of the sensory root of the gasserian ganglion and it avoids an operative approach through a field infiltrated with malignant tissue and which has been impaired by irradiation. In addition, there remains a moderate degree of tactile sensation in the areas enervated by the fifth, which is not true of the gangli-onectomy.

RESULTS

No attempt has been ma 'e to tabulate percentages as the series is too small to make such estimates accurate. One case would change the percentage figures by too great an amount. None of the 3 patients who are living and free of evidence of the disease has survived more than two and one-half years. Three others are alive but with active disease. These 3 were practically hopeless when first seen. The results are modified by the fact that all patients are given treatment, no matter how far advanced the disease is when first seen. This is observed in the tabulation which shows

that 7 patients survived only six months or less. Five of those had far advanced intracranial extension before treatment.

The degree of malignancy is much higher in those under twenty. Metastases occur earlier, intracranial extension is more rapid and severe and distant metastases more frequent. The process is more apt to be prolonged and amenable to treatment in the age group above fifty unless the general physical condition is poor.

SUMMARY

Transitional ephthelial cell carcinoma of the nasopharynx is not a rare disease. The diagnosis is often made too late for successful treatment. It affects all ages and sexes and is exceedingly malignant in children and young adults.

The most common site of the primary lesion is in or near the fossa of Rosenmüller or the pharyngeal tonsils. One of the earliest symptoms is referable to obstruction of the eustachian tube. Later symptoms are referable to a polypoid obstruction of the nasopharynx, invasion of the cranial cavity and metastases to the lymph nodes of the neck. Distant metastases are common.

Radiation therapy is the accepted method of treatment and offers the most hope at this time, whether it be complete arrest or palliation. Those cases treated before metastases or intracranial extension has occurred can expect the best results.

I am greatly indebted to Drs. R. E. Semmes, Wm. D. Stinson and John J. Shea for their permission to use these cases and their aid in assembling the necessary clinical information.

REFERENCES

1. Bach, A. C., Lederer, F. L., and Palevsky, S. N. Nasopharyngeal carcinoma. *Arch. Otolaryng.*, 1940, *31*, 529–539.
2. Cappell, D. F. On lympho-epithelioma of nasopharynx and tonsils. *J. Path. & Bact.*, 1934, *39*, 49–64.
3. Crowe, S. J., and Baylor, J. W. Benign and malignant growths of nasopharynx and their treatment with radium. *Arch. Surg.*, 1923, *6*, 429.
4. Ewing, J. Lymphoepithelioma. *Am. J. Path.*, 1929, *5*, 99–107.
5. Ewing, J. Radiosensitive epidermoid carcinomas. Am. J. Roentgenol. & Rad. Therapy, 1929, *21*, 313–321.
6. Ewing, J. Neoplastic Diseases. Fourth edition. W. B. Saunders Co., Philadelphia, 1940.
7. Frank, I., Lev, M., and Blahd, M. Transitional cell carcinoma of upper respiratory tract. *Ann. Otol., Rhin. & Laryng.*, 1941, *50*, 393–420.
8. Gardham, A. J. Endothelioma of nasopharynx; infiltrating tumour at base of skull. *Brit. J. Surg.*, 1929–1930, *17*, 242–263.
9. Jacod, M. Sur la propagation intracranienne des sarcomes de la trompe d'eustache; syndrome du Carrefour petrosphenoidal. *Rev. neurol.*, 1921.
10. Krompecher, E. Der Basalzellenkrebs. G. Fischer, Jena, 1903.
11. Lenz, M. Roentgen therapy of primary cancer of nasopharynx. Am. J. Roentgenol. & Rad. Therapy 1942, *48*, 816–832.
12. Martin, C. L. Complications produced by malignant tumors of nasopharynx. Am. J. Roentgenol. & Rad. Therapy 1939, *41*, 377–390.
13. Martin, H. E. Treatment of pharyngeal cancer. *Arch. Otolaryng.*, 1938, *27*, 661–691.
14. Martin, H. E., and Blady, J. V. Cancer of nasopharynx. *Arch. Otolaryng.*, 1940, *32*, 692–727.
15. New, G. B. Highly malignant tumors of nasopharynx and pharynx. *Tr. Am. Acad. Ophth.*, 1931, *36*, 39–44.
16. Olivecrona, H. Tractotomy for relief of trigeminal neuralgia. *Arch. Neurol. & Psychiat.*, 1942, *47*, 544–564.
17. Quick, D., and Cutler, M. Transitional cell epidermoid carcinoma; radiosensitive type of intra-oral tumor. *Surg., Gynec. & Obst.*, 1927, *45*, 320–331.
18. Reverchon, and Coutard. *Bull. Oto-rhino-laryngol.*, 1921.
19. Salinger, S., and Perelman, S. J. Malignant tumors of epipharynx. *Arch. Otolaryng.*, 1936, *23*, 149–172.
20. Schmincke, A. Ueber lymphoepitheliale Geschwülste. *Beitr. z. path. Anat. u. z. allg. Path.*, 1921, *58*, 161–170.
21. Sjöqvist, O. Studies on pain conduction in trigeminal nerve; contribution to surgical treatment of facial pain. *Acta psychiat. et neurol.*, supp. 17, 1938, pp. 1–139.
22. Trotter, W. On certain clinically obscure malignant tumors of nasopharyngeal wall. *Brit. M. J.*, 1911, *2*, 1057–1059.
23. Weinberger, L. M., and Grant, F. C. Experiences with intramedullary tractotomy; studies in sensation. *Arch. Neurol. & Psyciat.*, 1942, *48*, 355–381.
24. Woltmann, H. W. Malignant tumors of nasopharynx with involvement of nervous system. *Arch. Neurol. & Psychiat.*, 1922, *8*, 412.

CALCIFICATION IN THE DUCTUS ARTERIOSUS*

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THE roentgenographic demonstration of calcification in the mitral and aortic valves, annulus fibrosus and coronary arteries has been described by various authors and is now commonplace. Calcification in the arch of the aorta, pericardium, myocardium and endocardium is also well known.[1,2,3,4,5] No attempt has been made to search the literature completely, but to the best of our knowledge calcification in the ductus arteriosus has not been recognized during life, although various authors examining autopsy material have described microscopic areas of calcification in this structure. Jager and Wollenman,[6] in a careful study of the ductus arteriosus in 71 cases, representing a range from 28 mm. fetuses to adults eighty years of age, state that hyalinization, calcification and even cartilage formation occur in the older age groups. They note that the intima of the pulmonary artery and aorta becomes thickened over the obliterated ends of the ductus arteriosus and that atheromatous plaques in this region are a common occurrence in the aortas of adults, even in the absence of atheromatous lesions elsewhere in the aorta.

MATERIAL

Our interest in the occurrence of calcification in the ductus arteriosus has been stimulated by finding relatively marked calcification in this structure in an infant who came to autopsy at the age of nine months and fourteen days and also by the roentgenograms of 3 other patients, 2 infants and 1 child, which seem to reveal calcification in the ductus.

While most types of calcification in and around the heart are best recognized by roentgenoscopic examination, the calcified areas in our 3 living cases have been shown first in roentgenograms and in only 1 case has it been possible to confirm it by roentgenoscopy. This is not surprising as such calcified areas are very small, but as the body thickness at these ages is slight, roentgenograms show very fine detail provided that movement is prevented by short exposure time. Slightly overpenetrated chest roentgenograms are necessary to show the shadows distinctly.

CASE REPORTS

CASE I (Autopsy No. A-44-24). Joan P. This white female infant was admitted to another hospital at the age of three and a half months where a diagnosis of a feeding disturbance was made. She remained in that institution for sixteen days and at that time the blood Wassermann and tuberculin tests were found to be negative. Feeding difficulty persisted to some extent following her discharge and three convulsions occurred when she was eight months of age. She did well for the next month but died rather suddenly at the age of nine months and fourteen days at the Protestant Foster Home Centre following three more convulsions.

Postmortem examination at the Children's Memorial Hospital showed that there was a rounded perforation in the posterior wall of the stomach with generalized peritonitis. Bacteriological examination of the peritoneal contents revealed multiple organisms. The remainder of the examination was negative except for the ductus arteriosus which was closed but felt firm and gritty. There was no abnormality of the heart. Roentgenographic examination of the removed specimen confirmed the presence of a calcified area in the ductus arteriosus and showed it to be 1 cm. in length and from 1 to 3 mm. in width (Fig. 1). A portion of this calcification had a crescentic outline. Unfortunately, no roentgenograms were ever made during life, but it seemed obvious that there was sufficient calcification so that it could have been recognized with ease in a chest roentgenogram.

Microscopic examination of serial sections of the ductus arteriosus using hematoxylin eosin, trichrome, and elastic tissue stains revealed the typical structure of a small caliber artery, with

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several exceptions. The internal elastic lamina was much more prominent than normal, and the vessel was closed. The lumen was occluded throughout the length of the vessel by a relatively acellular hyaline connective tissue in which a few blood vessels were visible. In this hyaline connective tissue there were irregular plaques and granules of calcified material. Adjacent to some of the larger plaques of calcium there were cells which resembled osteoblasts, so that an impression of new bone formation was given (Fig. 2).

The amount of calcium present in the obliterated lumen varied considerably from one end of the vessel to the other and was more plentiful at the aortic end. No calcification was found in the media or adventitia.

Fig. 1. Case I. Roentgenogram of removed heart and great vessels showing extensive calcification in the ductus arteriosus. One pin has been placed in the aorta and the other in the pulmonary artery so that the ductus lies between them with the calcification opposite the point of the arrow.

Case II (Hosp. No. 24,239). G. L., a white male infant who was admitted to the Children's Memorial Hospital at the age of eight months. Except for a period of five months he was observed in hospital until he was twenty-six months of age. The entrance complaint was failure to gain weight and when he first came under observation he weighed only 11 pounds. In spite of adequately supplemented diet his weight had increased to only 13 pounds when he was finally discharged. No satisfactory explanation for his failure to gain was found in spite of the most exhaustive investigations all

Fig. 2. Case I. Photomicrograph of the ductus arteriosus showing islands of calcium in the fibrous tissue obliterating the lumen. Hematoxylin and eosin stain, 30×.

of which were either inconclusive or non-contributory. The tuberculin and Wassermann tests were negative and at no time were any adventitious heart sounds noted. No abnormalities of the blood calcium, phosphorus or phosphatase were present.

Roentgenographic examination of the chest

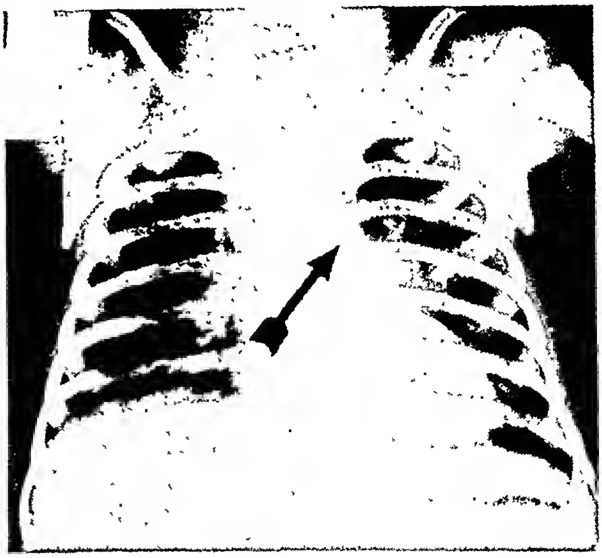

Fig. 3. Case II. Posteroanterior roentgenogram of chest made at eight months of age. The calcified shadow is crescentic in outline and lies just to the left of the vertebral column opposite the fourth interspace posteriorly.

Fig. 4. Case ii. Right lateral view of chest at age of two years. Calcification is visible opposite the point of the black arrow.

was carried out on nine separate occasions during his stay in hospital. The heart was not enlarged. Rather linear increased density persisted at the right base, and this neither increased nor diminished appreciably. The only other positive finding was a crescentic area of calcification 3 mm. in diameter situated just to the left of the vertebral column on a plane opposite the second rib anteriorly and fourth interspace or fifth rib posteriorly (Fig. 3). The exact relationship to the ribs varied slightly in different roentgenograms suggesting that it was situated neither directly anteriorly nor posteriorly in the chest. As time went by, the shadow gradually became slightly denser and formed a slightly more complete circle but there was very little if any increase in diameter. Just before he was discharged it was visualized in right and left anterior oblique and direct lateral views (Fig. 4 and 5). The length was approximately 1 cm. and its posterior limit was about the same distance in front of the vertebral column. It lay just to the left of the bifurcation of the trachea and roentgenoscopic examination indicated that it moved with the pulsations of the adjacent vascular shadows.

Case iii (Hosp. No. 26,805). J. C. L. This white male infant was first admitted to the Children's Memorial Hospital at the age of nineteen days when a diagnosis of pyodermia was made. He was discharged as improved thirteen days later. At the age of five and a half months he was re-admitted for fifteen days. On this occasion the diagnoses were infected eczema, right-sided lobular pneumonia and phimosis. General investigation at this time revealed a negative Wassermann test, negative urinalysis, serum calcium 9.8 mg. per 100 cc., plasma phosphorus 5.46 mg. per 100 cc., and serum phosphatase 13.9 Bodansky units. The Patch test had been negative at the time of his first admission and a tuberculin test was not performed. Examination of the heart revealed no enlargement nor murmurs.

Roentgenographic examination of the chest on the day of his second admission revealed a linear type of infiltration extending throughout a good deal of the right lung. There was a congenital anomaly involving the second rib on the right, a bony projection extending upward toward the first rib in the anterior axillary line. In addition, there was a tiny calcified area about 2 mm. in diameter lying 5 mm. to the left of the vertebral column opposite the second rib anteriorly and the fourth interspace posteriorly. The presence of an artifact was excluded by a second roentgenogram made the same day, which showed exactly the same shadow.

The parents were persuaded to bring the infant back for re-examination on July 7, 1944, at which time he was exactly a year old. Postero-anterior, right and left anterior oblique and lateral roentgenograms of the chest were then made. The size of the calcified shadow had not changed appreciably and it was opposite the

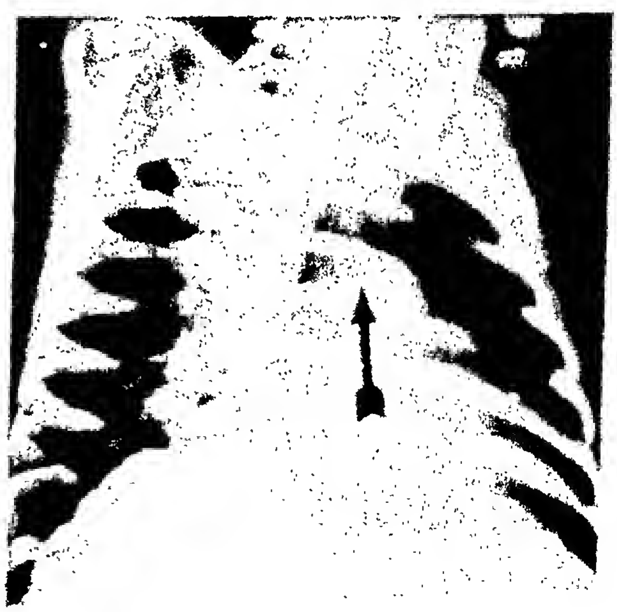

Fig. 5. Case ii. Right anterior oblique view of [illegible] showing calcification in the [illegible].

second rib anteriorly and sixth rib posteriorly just to the left of the vertebral column. In the right anterior oblique view, it was farther from the vertebral column, just to the left of the bifurcation of the trachea and opposite the right side of the second segment of the sternum. It could not be recognized in the lateral or left anterior oblique views.

Case iv (Hosp. No. 24,872). James P., a white male infant who was first seen in the Out-Patient Department at the age of twenty-one months at which time he was suffering from an upper respiratory infection with mild bronchitis. One year later when he was two years and nine months old he was admitted to the Children's Memorial Hospital suffering from a right upper lobe pneumonia, phimosis and a distended bladder. The blood Wassermann was negative and examination of the heart revealed no enlargement nor cardiac murmurs. He was discharged four days later.

A posteroanterior roentgenogram of the chest made on the day of admission showed somewhat faint consolidation in the right upper lobe. The only other finding of note was a ring-like shadow 3 mm. in diameter resembling calcification close to the left border of the vertebral column opposite the sixth interspace posteriorly and the upper margin of the second rib anteriorly (Fig. 6).

Re-examination of the chest six months later showed the lung fields to be clear. The calcified shadow was again visible and had not changed in the slightest degree in size, shape, density or position. It was faintly shown in a right anterior oblique view lying just to the left of the bifurcation of the trachea opposite the fifth interspace posteriorly. The tuberculin test was negative at this time.

DISCUSSION

Extensive calcification in the ductus arteriosus at the age of eight months and fourteen days is conclusively proved in Case i as shown by postmortem examination. It would seem that this calcification was sufficiently dense so that it could have been readily shown in a roentgenogram had the chest been roentgenographed before death. No other abnormalities of the heart or great vessels were found and the ductus arteriosus was closed.

A similar type of calcification has been repeatedly shown in Case ii from the age of eight months up to the age of twenty-six months. This occupies a position in the chest corresponding to the ductus arteriosus, as shown by examination in four planes, and it pulsates with the adjacent vascular structures. During this eighteen months' period it has become a little denser but not appreciably larger. Although this child is an example of extreme marasmus of unexplained origin it has never been possible to demonstrate any abnormality of the heart or great vessels, and the findings

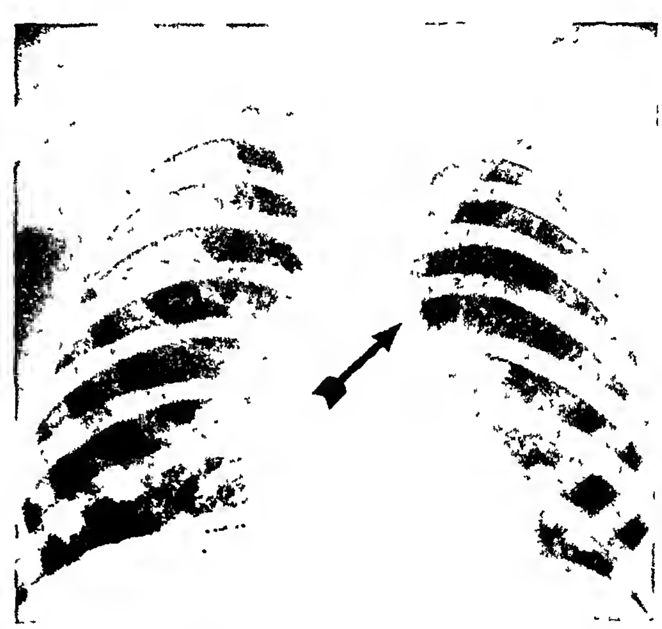

Fig. 6. Case iv. Roentgenogram of chest made at age of twenty-one months. The calcified shadow lies opposite the point of the arrow and while difficult to see in this reproduction it is plainly visible in the original roentgenogram. Somewhat faint consolidation is present in the right upper lobe.

and course have tended to exclude tuberculosis.

In Case iv the calcification is less evident, but its position is practically identical to that in Case ii. There has been no change during the six months' period that this child has been under observation. Except for one attack of pneumonia, an upper respiratory infection and phimosis he has thrived in a normal manner.

The calcification in Case iii occupies the same position as that in Cases ii and iv

but it is of more homogeneous density and not of a ring-like or crescentic shape. It has only been shown in posteroanterior and right anterior oblique roentgenograms, but there seems to be good evidence that it lies in the ductus. It was first noted at five and a half months, the youngest age of any of our patients.

As a general rule, calcification in the chest in infants and children should be considered tuberculous in nature until proved otherwise. However, tuberculous calcification before the age of six months is extremely rare and it is uncommon under the age of one year. When present, it is usually accompanied by extensive pulmonary infiltration and glandular enlargement and there is almost invariably clinical evidence to support a diagnosis of tuberculosis. A crescentic type of calcification such as that shown in Cases II and IV must be very unusual in tuberculosis, particularly when it is shown that no appreciable change occurs over a relatively long period of time. In the cases reported above no significant glandular enlargement has been demonstrated on any occasion either in the chest or elsewhere in the body. In Case II there are chronic changes in the right lung, but these have not increased nor decreased, neither have they calcified and all the other evidence including the tuberculin test has been against a tuberculous etiology. In Cases III and IV there have been typical pneumonias which have resolved rapidly following sulfonamide therapy and subsequent roentgenograms have shown complete clearing.

There is nothing to suggest that the ductus arteriosus is patent in any of our patients. Calcification has not been observed by us in any of the 18 cases of patent ductus arteriosus which have been operated on by Dr. Dudley Ross, at the Children's Memorial Hospital.

SUMMARY AND CONCLUSIONS

A proved example of moderately marked localized calcification in the obliterated lumen of the ductus arteriosus of an infant nine and a half months of age is reported. No other congenital anomalies were present. Calcification presumably in the ductus arteriosus has been found in the roentgenograms of the chests of two other infants and also in one child two years and nine months of age.

Although such macroscopic calcification does not seem to have been reported previously, it is probable that other instances may be found now that the possibility is known to exist. It does not appear to be of any clinical importance, but it should be differentiated from other lesions such as tuberculosis with which it may be confused.

REFERENCES

1. Cutler, E. C., and Sosman, M. C. Calcification in the heart and pericardium. Am. J. Roentgenol. & Rad. Therapy, 1924, *12*, 312–320.
2. Sosman, M. C., and Wosika, P. H. Calcification in aortic and mitral valves, with report of 23 cases demonstrated in vivo by roentgen ray. Am. J. Roentgenol. & Rad. Therapy, 1933, *30*, 328–348.
3. Sosman, M. C. Technique for locating and identifying pericardial and intracardiac calcifications. Am. J. Roentgenol. & Rad. Therapy, 1943, *50*, 461–468.
4. Roesler, H. Clinical Roentgenology of Cardiovascular system. Second edition. Charles C Thomas, Springfield, Illinois, 1943.
5. White, P. D. Heart Disease. Third edition, Macmillan Co., New York, 1944.
6. Jager, B. V., and Wollenman, O. J., Jr. Anatomical study of closure of ductus arteriosus. *Am. J. Path.*, 1942, *18*, 595–613.

ROENTGENOLOGICAL ASPECTS OF THERAPEUTIC PNEUMOPERITONEUM IN PULMONARY TUBERCULOSIS*

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ALTHOUGH the use of artificial pneumoperitoneum in the treatment of pulmonary tuberculosis has been accorded general acceptance during the last decade, the roentgenological literature contains very little information on this subject. This is the more surprising since artificial pneumoperitoneum has been used extensively in roentgenological practice for diagnostic purposes and has also been recently recommended by Sante[17] as an adjuvant in the roentgen therapy of pelvic organs. Moreover, its application in intra-abdominal tuberculosis has been a standard procedure for almost half a century.

The history and rationale of pneumoperitoneum therapy in pulmonary tuberculosis are very interesting. The observations on which this form of treatment is based go back as far as Hippocrates and Sydenham (Fishberg[7]). They are founded on the experience that tuberculous women get along unusually well during the second and third trimesters of pregnancy, i.e. during that period of gestation when a marked physiological elevation of the diaphragm exists. This experience is so striking that, in 1700 and 1800 Cullen and Warren, respectively, recommended pregnancy in the treatment of pulmonary tuberculosis. A phthisiologist of the immense experience of Fishberg states that he never saw a pregnant woman die of tuberculosis.[7] On the other hand, we all are familiar with the frequent disastrous results which follow this temporary improvement after parturition, i.e. after the physiological elevation of the diaphragm has ended and the diseased lung has expanded again. One of the original aims of pneumoperitoneum application, therefore, was to continue this diaphragmatic elevation post partum by substituting air for the enlarged uterus.

The technique of therapeutic pneumoperitoneum is not different from that employed in diagnostic pneumoperitoneum. A detailed description may therefore be dispensed with. There is still no agreement about the best location for the air injection: some prefer McBurney's point; some, Rovsing's point; some, the midline; some, other points near the umbilicus, while still others advocate the so-called "subphrenic route" (just below the site of the costophrenic angle).

Some employ local anesthesia; others consider it unnecessary.

Sterilized atmospheric air, oxygen or nitrogen is used. Dependent on the type of gas used, the terms of "pneumoperitoneum," "oxyperitoneum" or "nitroperitoneum" have been employed by different authors. This differentiation is not without significance from a clinical viewpoint since, to a certain degree, the gases used determine the time of absorption and, consequently, the necessity of refills. While refills with oxygen are necessary about twice a week, they may, as a rule, be limited with air to once a week and with nitrogen to about once every two weeks. In intra-abdominal lesions there is also supposed to exist a difference in curative effect, and for this purpose oxygen is generally preferred. In a purely roentgenological consideration, however, this difference may be neglected, and the term "pneumoperitoneum" is therefore used comprehensively in this paper to include all types of gases used.

The amount of gas injected is increased,

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as a rule, with each successive injection, starting with about 200 to 500 cc. until an optimum of about 1,500 cc. is reached. The injections should be done under both manometric and roentgenoscopic control. Extreme pressure is to be avoided since it may interfere with the patient's intake of food and so may hasten the clinical downward course.

The total duration of pneumoperitoneum treatment varies according to symptoms and results. Like pneumothorax, it should not be extended indefinitely.

The indications for pneumoperitoneum treatment in pulmonary tuberculosis have been formulated by Banyai,[1,2,3] Hobby,[10] Stokes,[18] and others.

Pneumoperitoneum may be applied either (1) as an independent therapeutic agent or (2) preparatory or supplementary to other forms of collapse therapy.

As an *independent measure*, pneumoperitoneum appears indicated in cases in which collapse therapy seems advisable but in which the other more orthodox forms of such therapy (like pneumothorax, phrenic block or thoracoplasty) are unsuitable or too hazardous. This postulate applies especially to cases with considerable bilateral involvement and extensive pleural adhesions; cases of severe pulmonary hemorrhage which cannot be controlled by any other means; then women following pregnancy (especially when pneumothorax cannot be induced); cases with reactivation after abandonment of pneumothorax; cases of advanced age and debility, and, finally, cases in which pulmonary tuberculosis is complicated by intestinal or peritoneal tuberculosis, by basal bronchiectasis, basal emphysema or allergic bronchial asthma.

Burge[5] includes as indicated all cases in which no functioning lung tissue can be spared since, in his experience, pneumoperitoneum does not tend to increase dyspnea. He further adds causes of unexplained chronic abdominal pain, vomiting and repugnance to food.

However, the chief field of pneumoperitoneum treatment lies in its combination preparatory or auxiliary to other forms of collapse therapy.

Rudman[16] recommends pneumoperitoneum as a *trial measure* to determine diaphragmatic mobility or freedom from interfering subdiaphragmatic adhesions prior to phrenic interruption or preparatory for radical surgery. Kaufman[11] believes that, by pneumoperitoneum, thoracoplasties can occasionally be prevented and that, employed before pneumothorax is attempted or immediately following the discontinuance of an ineffective pneumothorax, many complications of pneumothorax therapy may be avoided.

As an addition to *phrenic nerve block*, pneumoperitoneum is indicated if the elevation of the diaphragm is insufficient or when, despite an apparently satisfactory diaphragmatic rise, cavities persist and the sputum remains positive.

According to Raine[14] the combination of pneumoperitoneum and phrenic block may double the effective (unilateral) collapse achieved by diaphragmatic paralysis alone, while Brian and Ricen[4] estimate that, used without preliminary nerve crush, pneumoperitoneum is only 25 per cent effective.

As an addition to *artificial pneumothorax*, therapeutic pneumoperitoneum is indicated when relaxation of the basal portions of the lung is desirable but cannot be achieved by pneumothorax alone on account of adhesions or other impediments.

Similarly, *thoracoplasty or the paraffin pack* may be supplemented by pneumoperitoneum when lesions in distant portions of the lung remain active.

Undoubtedly the best results are obtained in cases where pneumoperitoneum can thus be combined with other forms of collapse therapy. In this way pneumoperitoneum treatment may reach lesions which remain uninfluenced by other measures. Rilance and Warring,[15] for instance, found that, by a combination of pneumoperitoneum and phrenic crush, the best results were obtained in cavities of the generally less accessible lower lung zone. A compari-

son of indications and results shows that pneumoperitoneum neither competes with, nor is intended to replace, the other forms of tuberculosis therapy.

Needless to say, pneumoperitoneum should not be reserved as a desperate last resort for hopeless cases; such use would only serve to discredit the method.

As contraindications to pneumoperitoneum Vajda,[21] Banyai and Stokes enumerate the following: (1) complete fixation and non-mobility of the diaphragm on the diseased side; (2) stiff-walled cavities or acute miliary disease; (3) reduction of the vital capacity of the lungs to less than one-third; (4) cardiac decompensation or diseases of the coronary artery, and (5) marked arteriosclerosis, amyloidosis or renal disease.

One definite advantage of the method is evident: its complete reversibility compared with phrenic block or thoracoplasty. From pneumothorax, which usually is only little less reversible, it distinguishes itself by the relative paucity of untoward sequelae and complications.

Among immediate sequelae are mentioned shoulder pain (similar to that experienced in liver or gallbladder disease); a feeling of tightness across the upper abdomen and the lower chest (most prominent after induction and the initial refills), and, occasionally, nausea and vomiting, especially in toxic patients.

The complications reported in the medical literature comprise ascites, intestinal perforation (very rare), peritoneal inflammation, atrophy of the diaphragm, air embolism, massive atelectasis, accidental pneumothorax, mediastinal emphysema, cardiac decompensation, enlargement of inguinal and umbilical hernias, and scrotal pneumocele (Monto and Bradford[13]).

It is obvious that in the determination and evaluation of both indications and contraindications as well as in the technique of administration and the diagnosis of the complications, roentgenoscopic and roentgenographic examinations are indispensable. In all these questions the roentgenologist may be of great help to the phthisiologist.

In the application of pneumoperitoneum, manometric measurements should be supplemented, as mentioned above, by roentgenoscopic control. The demonstration and evaluation of the type and extent of the pulmonary lesions, of pleural adhesions, diaphragmatic excursion, bronchiectasis, cardiovascular and renal disease, gastrointestinal complications, etc., belong to the realm of roentgenologic diagnosis.

Of equally great importance are the roentgenologic determination and evaluation of the direct and remote effects of the pneumoperitoneum treatment.

The roentgenologically directly observable effects of pneumoperitoneum are: (1) elevation of the diaphragm (which, as a rule, is bilateral though frequently unequal on both sides, and which may reach 10 cm. or more) combined with a corresponding limitation of diaphragmatic movements; (2) diminution of lung volume (which may amount to 15 to 35 per cent reduction of chest capacity) combined with compression of cavities, "crowding" of the bronchovascular markings and corresponding changes in the appearance of tuberculous lesions as well as of the heart and mediastinum; (3) separation of the subphrenic viscera, especially the stomach, liver and spleen, from the diaphragm, and (4) disappearance of intra-abdominal adhesions.

The effectiveness of the pneumoperitoneum and the final results depend on these factors which must be ascertained by clinical and roentgen examination and which demand close medical supervision. Whether the healing process proper is more the result of pulmonary rest, of better drainage of the bronchial tree and the cavities, of pulmonary congestion, lymph stasis or anoxemia lies beyond the scope of roentgenological observation.

Of complications ascites is probably the most frequent finding in the roentgenogram. According to Fowler[8] it occurs in about 3.8 per cent of the cases but rises to 45 per cent in terminal cases according to Trimble, Eaton and Moore.[20]

FIG. 1. Case 1. Extensive exudative cavernous changes in right lower and middle lobes and in left upper lobe.

During the past year, I have had opportunity roentgenologically to observe 61 tuberculous patients treated with pneumoperitoneum at the National Jewish Hospital in Denver. This means that the method, either independently or in connection with other forms of collapse therapy, was employed in about 25 per cent of all patients. Thirty-six of the patients were men, 25 were women. In the large majority of cases the pulmonary involvement was bilateral and, in a high percentage, pneumoperitoneum was auxiliary to phrenic block or pneumothorax. In 5 cases, it was combined with thoracoplasty; in 1 case, with Monaldi cavity drainage. The youngest patient of this series was ten years old, the oldest [illegible]; [illegible] per cent of the patients were more than thirty years old. Five patients were children [illegible] Spanish-American [illegible].

The duration of pneumoperitoneum treatment varied [illegible]

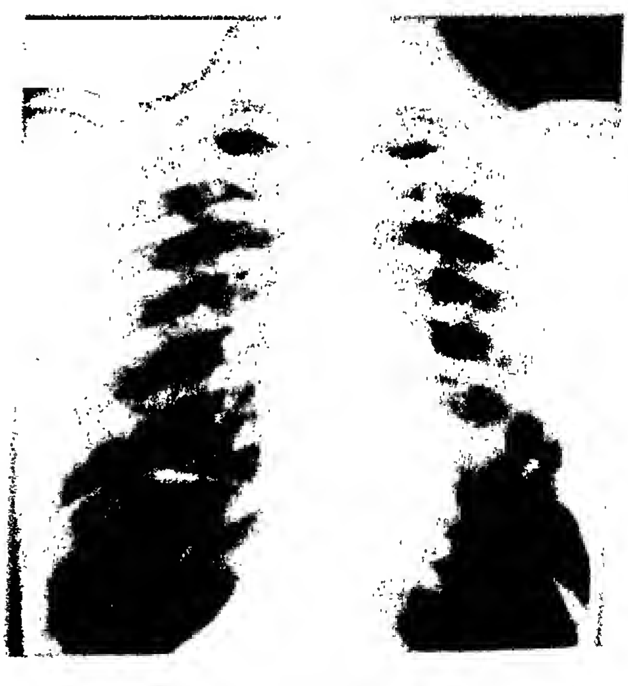
While the usual [illegible]

curred, none of these cases suffered from the severer complications which have been pointed out in the literature.

As a matter of fact, the scarcity of untoward symptoms and the absence of complications undisputably attributable to pneumoperitoneum treatment was most surprising. Only 4 patients presented symptoms that called for roentgen examination of the gastrointestinal or genitourinary tract. Considering the large number of tuberculous patients who "normally" have such complaints, it almost appears (as has been claimed by some authors) that pneumoperitoneum exerts a definitely beneficial influence on these organs.

Three deaths occurred among patients of this series. In none of these deaths could a causal connection between type of treatment and fatal outcome be assumed.

It is, of course, impossible to judge definitely about final success or failure in many cases of such an eminently chronic and unpredictable disease. This is particularly true if the pneumoperitoneum treatment is of too short a duration to produce any appreciable effects or is only a minor factor in the clinical and therapeutic picture.



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However, in other instances fairly definite conclusions are permissible, and a few representative cases and significant roentgenograms will be briefly discussed.

CASE REPORTS

Case i. A. K., schoolboy, aged fourteen. A refugee from Germany, he was hospitalized for pulmonary tuberculosis two days after arrival in this country (July, 1941). Admitted to the National Jewish Hospital the following month he showed very extensive exudative cavernous involvement of the right lower and middle lobes as well as of the left upper lobe (Fig. 1). Phrenic crush was done in September, 1941, followed by artificial pneumoperitoneum two days later. In spite of a relatively moderate elevation of the diaphragm (about 4 cm. on the right, 2 cm. on the left), the pulmonary lesions have practically disappeared (Fig. 2). Sputum and temperature have been normal for over two years.

An important factor deserves mention in this connection, i.e. the advantage of pneumoperitoneum in children over a possibly complicated pneumothorax and over a mutilating thoracoplasty. We know that the latter two methods when applied during the years of development and physical growth may result in marked deformities of the chest and bony thorax. This danger is entirely absent in pneumoperitoneum treatment.

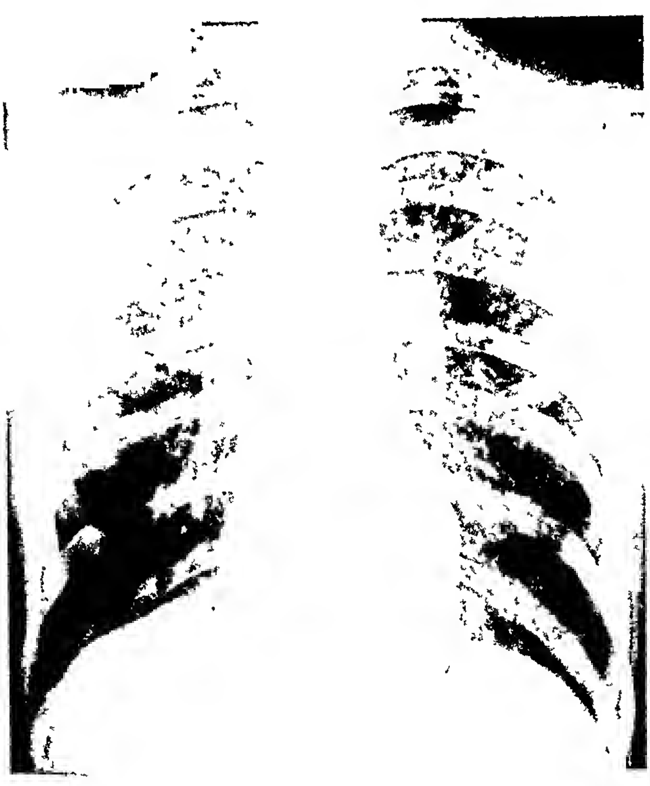

Fig. 3. Case ii. Far-advanced tuberculosis of both upper lobes.

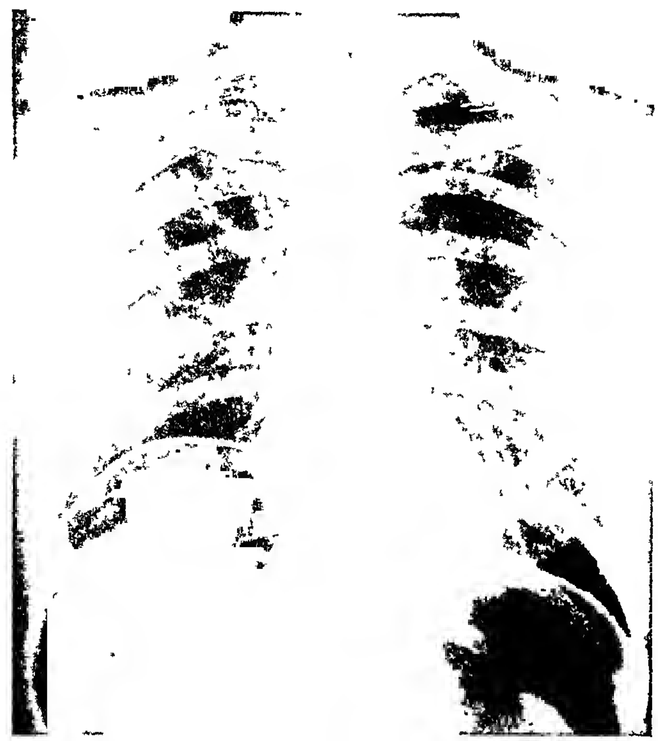

Fig. 4. Case ii. Status about one year following pneumoperitoneum and phrenic crush. Marked improvement of all pulmonary lesions.

Similarly good results were achieved by the combination of pneumoperitoneum and phrenic block in the following 2 cases.

Case ii. E. K., aged twenty, office boy, was admitted to the National Jewish Hospital in February, 1943, with the diagnosis of far-advanced tuberculosis of both upper lobes (Fig. 3). Because of extensive bilateral involvement and pleural adhesions, neither pneumothorax nor thoracoplasty was feasible, and pneumoperitoneum treatment was begun in May, 1943, supplemented three months later by right-sided phrenic crush. The result as seen in the roentgenogram taken on August 18, 1944, is highly satisfactory (Fig. 4). The right diaphragm has risen about 8 cm.; the left, about 5 cm. Of the previous extensive pulmonary involvement only some fibrosis in both upper lobes and some clouding of the right apex still remain. The patient feels well. The sputum has been negative for almost half a year; the temperature is normal.

Case iii. F. W., aged thirty-two, book-

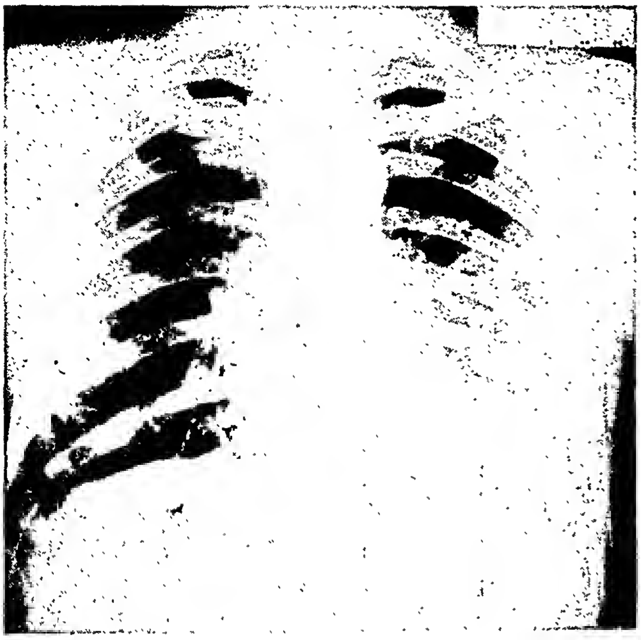

FIG. 5. Case III. Extensive exudative involvement and large cavity in left lower half. Numerous small type calcifications bilaterally.

keeper, with a history of pulmonary tuberculosis since 1934. Sanatorium treatment in 1935, and from July, 1940 to February, 1942. In the intervals, patient worked or went to school. Admitted to the National Jewish Hospital in December, 1942. The left phrenic nerve had been crushed in July, 1937, and was re-crushed in

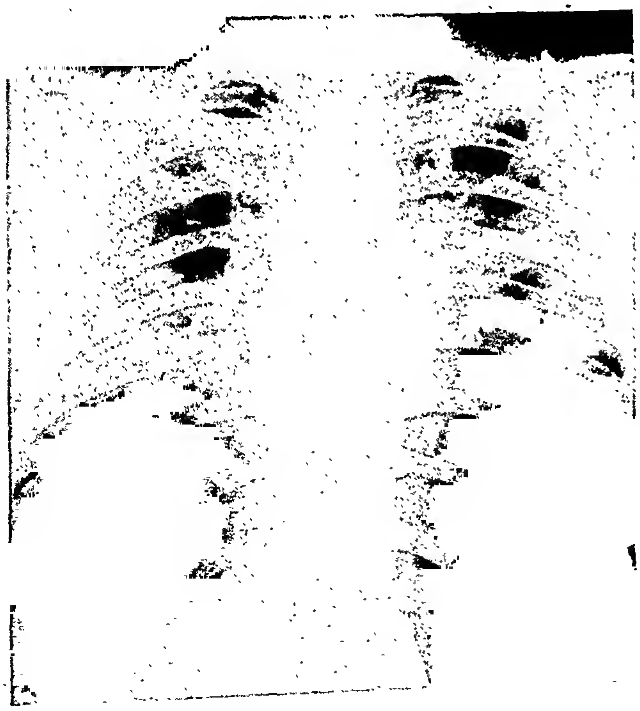

FIG. 6. Case III. Status after three years of pneumoperitoneum treatment combined with left phrenic crush and re-crush. Practically no more evidence of pulmonary lesions.

October, 1943. Pneumothorax was attempted but without success. On account of this failure and in view of the predominantly basal location of the lesions, artificial pneumoperitoneum was applied in November, 1940, and has been continued ever since, i.e. for a period of almost four years. During all this time, weekly fillings of 500 to 1,000 cc. of air have been administered, and a very marked bilateral elevation of the diaphragm has been maintained (about 8 cm. rise on the right and up to 14 cm. on the left). The intra-abdominal pressure after filling averages +10 to +12. Temperature and pulse which were elevated on admission are now normal; the sputum is negative.

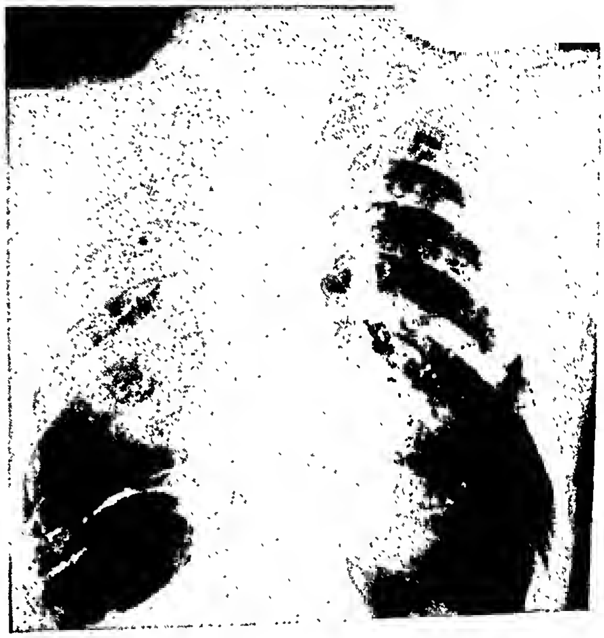

FIG. 7. Case IV. Limitation of diaphragmatic rise by subphrenic adhesions. Fixation of hepatic flexure of colon between liver and diaphragm.

The roentgenogram before application of pneumoperitoneum (November 29, 1940) shows very great exudative changes and a large oval cavity in the left lower half combined with numerous small type calcifications scattered throughout both lung fields (Fig. 5). The second roentgenogram three years after initiation of the pneumoperitoneum treatment shows about 8 cm. rise of the right diaphragm and about 13 cm. rise on the left, compared with the pre-pneumoperitoneum roentgenogram. The previously prominent cavernous exudative lesions in the left chest have entirely disappeared (Fig. 6). The abdomen shows the typical "bunching together" of the viscera but it is worthy of note that, despite these marked intra-abdominal

changes, the patient is without symptoms or complaints.

CASE IV. This case, L. W., aged forty-nine, plasterer, demonstrates the limitation of pneumoperitoneum treatment in the presence of widespread subphrenic and abdominal adhesions. In spite of a large amount of subphrenic air, the elevation of the diaphragm is insufficient to produce any noticeable pulmonary changes (Fig. 7).

I shall conclude with a case which is less remarkable with regard to the pulmonary or therapeutic aspects than it is representative of the abdominal findings generally encountered in pneumoperitoneum.

FIG. 8. Case V. Thoracoplasty, right, with incomplete collapse and pneumoperitoneum. Exudative cavernous changes in left apex.

CASE V. I. T., aged thirty, school teacher, has been suffering from secondary pulmonary tuberculosis since 1930. Even before that time, in 1919, she spent some time in a sanatorium for childhood tuberculosis. In 1933, pneumothorax of the right side was applied but, due to pleural adhesions, the result was unsatisfactory. The following year, an unsuccessful attempt at pneumonolysis was made, followed by a phrenic crush. Then, in 1935, a three-stage right-sided thoracoplasty was performed but an extension of the tuberculous process to the left side with cavitation followed the operation. In January, 1940, patient was admitted to the National Jewish Hospital, and pneumoperitoneum treat-

FIG. 9. Case V. Status immediately following barium meal. Normal position and outline of stomach. (Prone position.)

FIG. 10. Case V. Status twenty-four hours following barium meal. Normal position of colon. (Prone position.)

FIG. 11. Case v. Intravenous pyelography. Normal filling of renal pelves and calices. Air accumulation in left abdominal region simulating large cyst. (Supine position.)

FIG. 12. Case vi. Postmortem examination. Appearance and position of chest and abdominal viscera practically identical with antemortem appearance.

ment was inaugurated in April, 1942. The effect of the diaphragmatic elevation has not been sufficient to enhance the incomplete collapse of the right lung materially nor have the exudative cavernous changes in the left apex been appreciably improved (Fig. 8).

The abdominal roentgenograms present the typical appearance of diagnostic pneumoperitoneum which needs no further explanation. The considerable difference in appearance and contrast between roentgenograms in the prone and erect positions and those taken in the supine position is primarily due to the difference in air distribution. In the prone views and in the erect views the air accumulation is most prominent under the domes of the diaphragm; the liver, kidneys and spleen are "bunched together" and very sharply contrasted and delineated. There is very little change in the roentgen appearance of the stomach and the intestinal tract. Following barium filling, the stomach and colon almost seem to float in a void and show practically normal outlines and position (Fig. 9 and 10). This fact explains the relative lack of untoward gastrointestinal symptoms even in extensive and protracted pneumoperitoneum treatment.

In the supine position, the typical appearance of pneumoperitoneum disappears, and the striking conglomeration and contrast of the viscera, especially the liver, kidneys and spleen, no longer exist. Instead of largely occupying the subdiaphragmatic spaces and upper abdominal areas, the air now occupies the highest level of the peritoneal cavity and may be difficult to trace. In our roentgenogram, the highest air bubble lies in the left abdominal region and has the appearance of a large cyst extending from the calices of the left kidney (Fig. 11).

In none of our cases of pneumoperitoneum were we able to diagnose ascites or other intra-abdominal complications (adhesions excepted) roentgenologically.

Postmortem roentgen examinations were obtained in the 3 patients who died during pneumoperitoneum therapy. A comparison with the roentgenograms taken previously showed that the rise of the diaphragm and the other changes produced by pneumo-

peritoneum persist essentially unchanged after death (Fig. 12, Case vi).

SUMMARY

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REFERENCES

1. Banyai, A. L. Therapeutic pneumoperitoneum. *Am. Rev. Tuberc.*, 1934, *29*, 603–627.
2. Banyai, A. L. Artificial pneumoperitoneum. *Med. Rec.*, 1938, *148*, 431–433.
3. Banyai, A. L. Principles of pneumoperitoneum treatment of pulmonary tuberculosis. *Dis. of Chest*, 1941, *7*, 402–406.
4. Brian, E. G., and Ricen, E. Collapse therapy of pulmonary tuberculosis; results with pneumoperitoneum. *U. S. Nav. M. Bull.*, 1941, *39*, 391–396.
5. Burge, F. W. Pneumoperitoneum, oxyperitoneum and nitroperitoneum in treatment of pulmonary and abdominal tuberculosis. *Dis. of Chest*, 1938, *4*, 14–18.
6. Clifford-Jones, E., and Macdonald, N. Pneumoperitoneum in collapse therapy of pulmonary tuberculosis. *Tubercle.*, 1943, *24*, 97–107.
7. Fishberg, M. Pulmonary Tuberculosis. Third edition. Philadelphia, 1922.
8. Fowler, W. O. Pneumoperitoneum in treatment of pulmonary tuberculosis. *Am. Rev. Tuberc.*, 1941, *44*, 474–478.
9. Friedman, L. J. Textbook of Diagnostic Roentgenology. D. Appleton-Century Co., New York, 1937.
10. Hobby, A. W. Pneumoperitoneum—adjunct to treatment of pulmonary tuberculosis. *Dis. of Chest*, 1938, *4*, 18–20.
11. Kaufman, C. J. Diaphragmatic paralysis and pneumoperitoneum in pulmonary tuberculosis. Read before Colorado State Medical Society, September, 1944.
12. Logie, A. J., Walker, H. A., and Stoddard, G. R. Control of massive pulmonary hemorrhage by pneumoperitoneum. *Ann. Int. Med.*, 1943, *19*, 685–690.
13. Monto, R. W., and Bradford, H. A. Scrotal pneumocele; complication of pneumoperitoneum. *Am. Rev. Tuberc.*, 1943, *47*, 537–539.
14. Raine, F. Paralysis of diaphragm in treatment of pulmonary tuberculosis. *Dis. of Chest* 1939, *5*, 56–57.
15. Rilance, A. B., and Warring, F. C., Jr. Pneumoperitoneum supplementing phrenic paralysis. *Am. Rev. Tuberc.*, 1941, *44*, 323–334.
16. Rudman, I. E. Pneumoperitoneum; its scope and limitations in treatment of pulmonary tuberculosis. *Am. Rev. Tuberc.*, 1943, *48*, 334–341.
17. Sante, L. R. Further experience with pneumoperitoneum as aid in pelvic irradiation. *Radiology*, 1943, *40*, 447–453.
18. Stokes, J. B. Pneumoperitoneum for pulmonary compression. *Illinois Med. J.* 1938, *73*, 137–147.
19. Trimble, H. G. Pneumoperitoneum in treatment of pulmonary tuberculosis. *Dis. of Chest*, 1938, *4*, 18–21.
20. Trimble, H. G., Eaton, J. L., and Moore, G. Pneumoperitoneum in treatment of pulmonary tuberculosis; local effects on peritoneum. *Am. Rev. Tuberc.*, 1939, *39*, 528–536.
21. Vajda, L. Ob das Pneumoperitoneum in der Kollapstherapie der beiderseitigen Lungentuberkulose angewandt werden kann? *Ztschr. f. Tuberkulose*, 1933, *67*, 371–375.
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REFERENCES

1. Banyai, A. L. Therapeutic pneumoperitoneum. *Am. Rev. Tuberc.*, 1934, *29*, 603–627.
2. Banyai, A. L. Artificial pneumoperitoneum. *Med. Rec.*, 1938, *148*, 431–433.
3. Banyai, A. L. Principles of pneumoperitoneum treatment of pulmonary tuberculosis. *Dis. of Chest*, 1941, *7*, 402–406.
4. Brian, E. G., and Ricen, E. Collapse therapy of pulmonary tuberculosis; results with pneumoperitoneum. *U. S. Nav. M. Bull.*, 1941, *39*, 391–396.
5. Burge, F. W. Pneumoperitoneum, oxyperitoneum and nitroperitoneum in treatment of pulmonary and abdominal tuberculosis. *Dis. of Chest*, 1938, *4*, 14–18.
6. Clifford-Jones, E., and Macdonald, N. Pneumoperitoneum in collapse therapy of pulmonary tuberculosis. *Tubercle.*, 1943, *24*, 97–107.
7. Fishberg, M. Pulmonary Tuberculosis. Third edition. Philadelphia, 1922.
8. Fowler, W. O. Pneumoperitoneum in treatment of pulmonary tuberculosis. *Am. Rev. Tuberc.*, 1941, *44*, 474–478.
9. Friedman, L. J. Textbook of Diagnostic Roentgenology. D. Appleton-Century Co., New York, 1937.
10. Hobby, A. W. Pneumoperitoneum—adjunct to treatment of pulmonary tuberculosis. *Dis. of Chest*, 1938, *4*, 18–20.
11. Kaufman, C. J. Diaphragmatic paralysis and pneumoperitoneum in pulmonary tuberculosis. Read before Colorado State Medical Society, September, 1944.
12. Logie, A. J., Walker, H. A., and Stoddard, G. R. Control of massive pulmonary hemorrhage by pneumoperitoneum. *Ann. Int. Med.*, 1943, *19*, 685–690.
13. Monto, R. W., and Bradford, H. A. Scrotal pneumocele; complication of pneumoperitoneum. *Am. Rev. Tuberc.*, 1943, *47*, 537–539.
14. Raine, F. Paralysis of diaphragm in treatment of pulmonary tuberculosis. *Dis. of Chest* 1939, *5*, 56–57.
15. Rilance, A. B., and Warring, F. C., Jr. Pneumoperitoneum supplementing phrenic paralysis. *Am. Rev. Tuberc.*, 1941, *44*, 323–334.
16. Rudman, I. E. Pneumoperitoneum; its scope and limitations in treatment of pulmonary tuberculosis. *Am. Rev. Tuberc.*, 1943, *48*, 334–341.
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18. Stokes, J. B. Pneumoperitoneum for pulmonary compression. *Illinois Med. J.* 1938, *73*, 137–147.
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21. Vajda, L. Ob das Pneumoperitoneum in der Kollapstherapie der beiderseitigen Lungentuberkulose angewandt werden kann? *Ztschr. f. Tuberkulose*, 1933, *67*, 371–375.
22. Woodford, L. G. Pneumoperitoneum with phrenic paralysis. *Dis. of Chest*, 1942, *8*, 296–301.

CONTRAST ROENTGENOGRAPHY OF THE PNEUMATIC CELLS OF THE TEMPORAL BONE

By MAX UNGER, M.D.
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WHEN an otologist prepares to operate on a case of mastoid disease, three questions on anatomy come up for consideration. First, is the mastoid cellular or solid? second, if cellular, how deeply and widely do the cells extend? and third, are the cells pneumatic or only spaces in cancellous bone?

The answers to these questions cannot be found by external inspection and palpation by the otologist. Even after the mastoid is opened and the cells exposed to the eye, it is difficult to answer the third question. It is not unusual for a surgeon, after exposing cell after cell, to remark "There is no use going farther, this is cancellous bone" and to stop further exploration.

Since the deep structures are hidden from sight and touch, the otologist must turn to the roentgenologist for the answers to these questions. The roentgenologist, however, using the conventional methods in vogue up to now, can give only partial help. He can answer the first two questions with excellent roentgenograms showing the most delicate tracery of bone formation. He can answer the third question, however, only inferentially. Given a roentgenogram that shows a number of cells grouped around the auditory canal in the mastoid region, it is reasonable to infer that the cells are mastoid cells. Operation will usually confirm the correctness of this inference. Such inferences, however, are not so easy when one deals with small cells around the periphery or in the petrous pyramid. Such cells, in fact, by reason of their small size and the amount and density of the surrounding bone, may not even appear in a conventional roentgenogram.

In order to differentiate between pneumatic and cancellous cells, I have devised the technique for contrast roentgenography of the temporal bone that I am about to describe. It can be used only where there is a perforated tympanic membrane, a mastoid fistula or both.

The procedure followed is, briefly, as follows. First, roentgenograms are taken in the conventional manner, including a view showing both mastoids and petrous bones from one exposure. Then an aqueous solution of a radiopaque salt is instilled into the middle ear and communicating cells. After this another series of roentgenograms is taken in the same positions as the first series. Comparison of the two series will show the cells that contain the opaque solution.

The technique of instilling an opaque solution into the tympanum and paratympanic cells is a new procedure and requires a more detailed description. It needs the closest cooperation between the otologist and the roentgenologist. Since the perforated drum membrane is usually accompanied by pus, swollen mucous membrane, and often polyps, it is necessary first to remove the pus from both tympanum and paratympanic cells and to shrink the soft tissues. The external auditory canal is cleaned by syringing or swabbing. Then the patient lies on his side on a table, with the diseased ear uppermost. A drop of a vasoconstrictor is instilled into the canal and allowed to act for about ten minutes. Then the external canal is filled with warm 2 per cent boric acid or sodium bicarbonate solution. This is allowed to seep in. The tip of a Siegle pneumatic otoscope is fitted tightly into the canal and the bulb is worked for about one minute. This causes alternate suction and pressure and creates a to and fro swishing of the fluid in the ear, helping to dislodge the pus and bring it to the sur-

face. After this the patient lies on his other side and the suction and pressure is applied while the ear is down. This draws the fluid out and allows air to replace it. This also is done for one minute. The patient turns the diseased ear up again and the same procedures are repeated five or six times till the washings return clear. The patient then lies with the affected ear down for five minutes to allow all fluid to drain out. The entire procedure takes thirty to forty minutes. Instead of an otoscope, a bulbous glass irrigator tip and a rubber bulb may be used. The use of a rubber bulb is very tiring on the hand and I have, therefore, installed a very slowly acting electric pump which makes about 60 revolutions per minute and can deliver suction and pressure at 150 mm. of mercury or less, as required.

After the ear is free of the cleansing solution, the patient is again turned with the affected ear up and the aqueous radiopaque solution is instilled into the canal. The pump is used again to help instill the fluid deeply. The patient is not turned over this

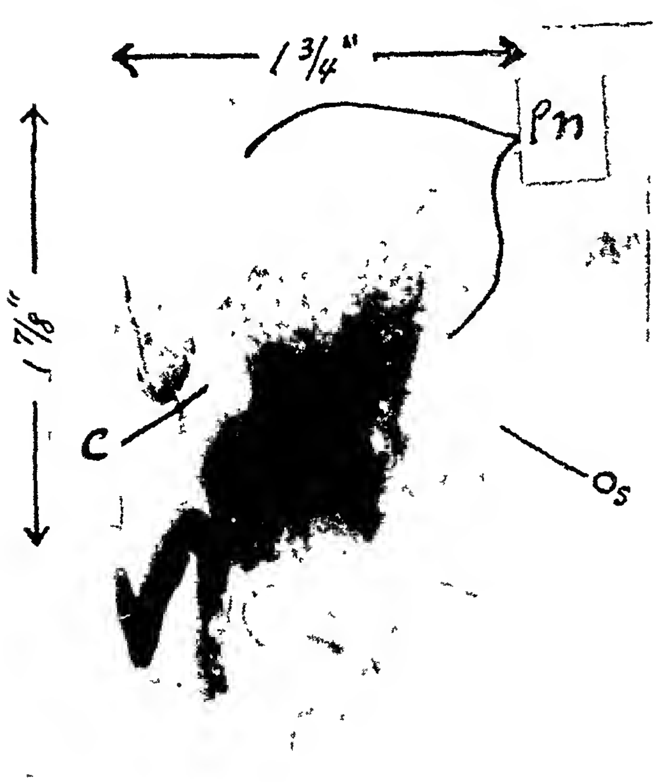

Fig. 1. Wet cadaver before injection of opaque material. *C*, canal; *Os*, bone cells; *Pn*, pneumatic cells.

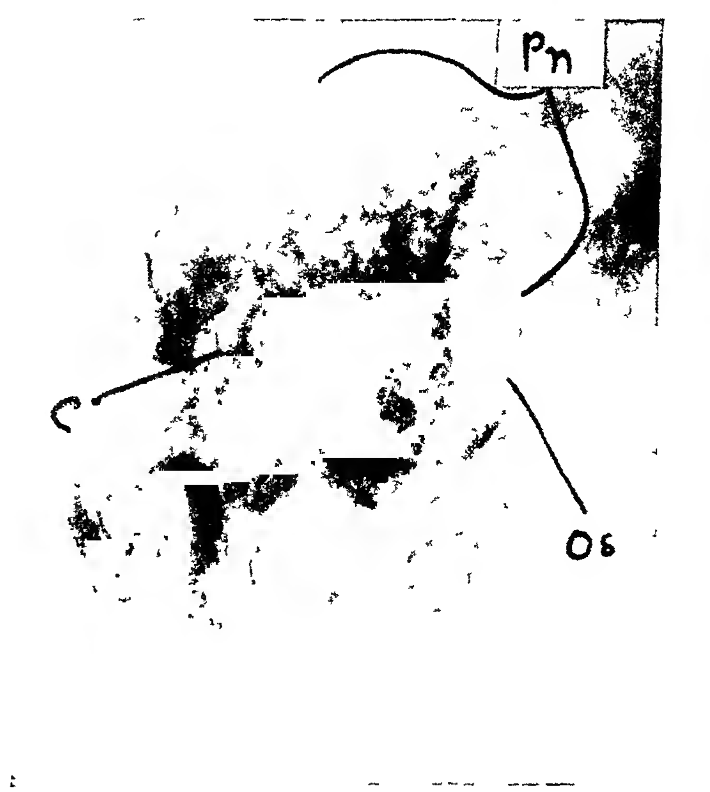

Fig. 2. Cadaver after injection of opaque material. *C*, canal; *Os*, bone cells; *Pn*, pneumatic cells.

time but is kept in the same position. If the opaque solution has disappeared from view, more is added. The capacity of the air cells is sometimes surprising. The cadaver specimen shown in the illustrations took 12 cc. of solution. The canal is now corked carefully to prevent leakage. A small medicine dropper bulb, closed end first, makes a good, comfortable stopper. If loose, its cavity can be packed to distend it. The second series of roentgenograms is now taken.

A study of the roentgenograms of a wet cadaver specimen shown in Figures 1, 2, 3 and 4 is revealing. Figure 1 is a lateral view of a temporal bone *before* opaque solution was injected. The network of very small cells, lettered *Os*, is the osseous framework; the network of large cells, lettered *Pn*, are the pneumatic cells. Figure 2 is a roentgenogram of the same specimen in the same position *after* injection of opaque solution and shows the same air cells more heavily outlined and also brings out some peripheral cells not visible in Figure 1, especially in the mastoid region.

Figures 3 and 4 show still more interest-

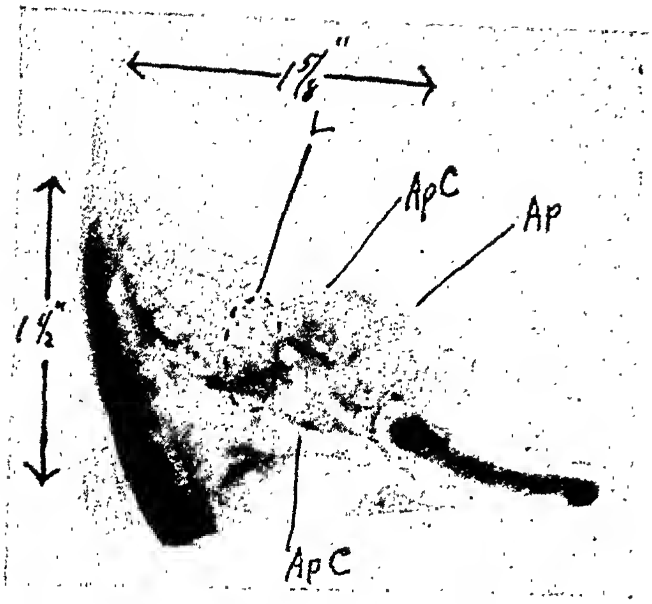

FIG. 3. Cadaver, horizontal view, before injection of opaque material. *L*, labyrinthine region; *Ap*, petrous apex; *ApC*, apical cells.

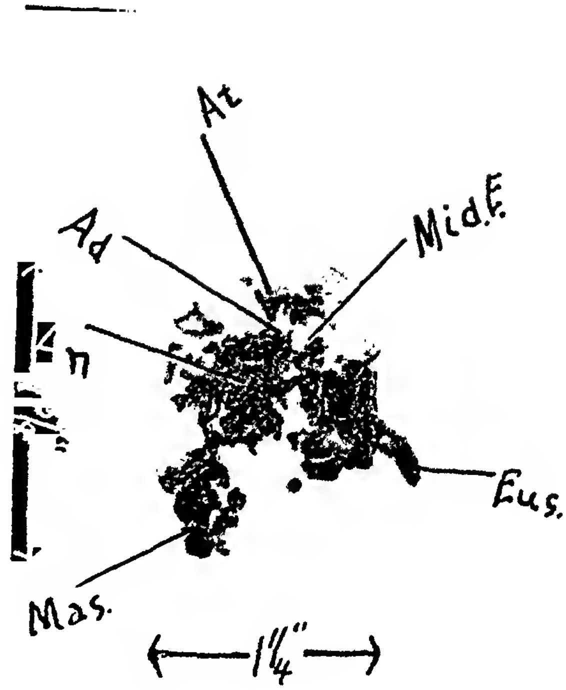

FIG. 5. Internal cast of previous specimen. Lateral view. *Eus*, eustachian tube; *Mid E*, middle ear; *At*, atticus; *Ad*, aditus; *An*, antrum; *Mas*, mastoid cells.

ing findings. They are horizontal views of the same specimen showing the whole length of the petrous pyramid. Figure 3 was taken before injection of opaque solution. The apex of the petrous bone can be clearly seen. The broken circle indicates the region of the cochlea and semicircular canals. Even without the opaque solution, a network of air cells can be seen overlying these structures and along the anterior and posterior borders of the petrous bone, cells can be seen that extend to within ½ inch of the petrous apex. In Figure 4, the same specimen in the same position *after* the in-

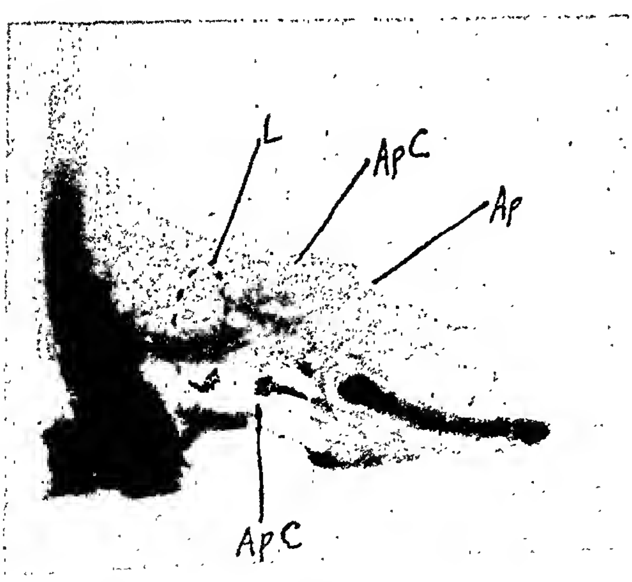

FIG. 4. Cadaver, after injection of opaque material. *L*, labyrinthine region; *Ap*, petrous apex; *ApC*, apical cells.

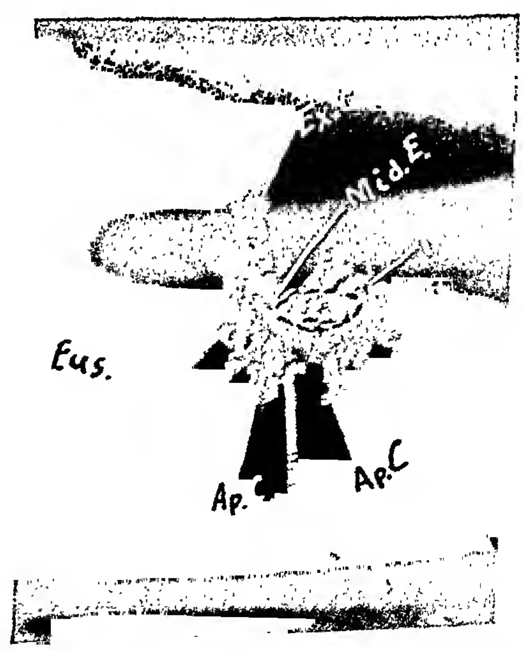

FIG. 6. Top view, previous specimen. *ExC*, external canal; *Eus*, eustachian tube; *Mid E*, middle ear; *Mas*, mastoid cells; *ApC*, apical cells.

jection of the opaque solution, the cells are more heavily outlined.

The importance of these findings is obvious. They show a continuous, if devious, aerial connection between the middle ear and petrous cells. This specimen is typical of many that I have studied. They undoubtedly offer an explanation of the path of infection in many, if not all, cases of petrous apicitis.

The presence of the opaque solution in the cells is positive proof that they are air cells, but any question of a shadow of a doubt is precluded by the findings in Figures 5 and 6. These are photographs of casts of the insides of the tympanum and paratympanic cells. The casts were made by injecting, under pressure, an acetone solution of a plastic (methyl methacrylate-polymer vinylite) through an opening in the drum membrane. After the plastic had solidified, the bone and soft tissues were dissolved by strong caustics, which did not act on the vinylite. The same specimen was used as in the previous studies. Before the cast was completely freed of its bony encasement, it was seen to approximate the dimensions shown in the roentgenograms (Fig. 1–4),

Fig. 7. Before injection of opaque material in patient.

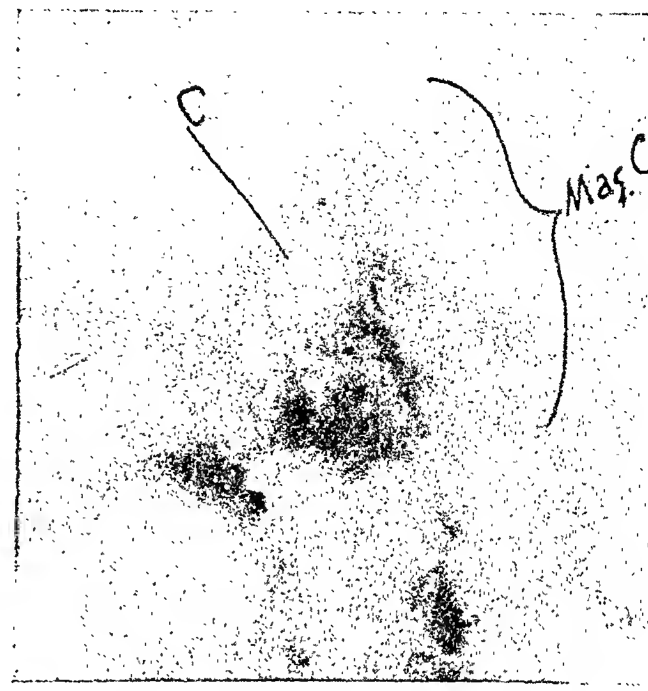

Fig. 8. Same patient, after injection of opaque material.

but as it was freed from the bone, many peripheral cells were so delicate and their connections so tenuous, that they fell off during handling. The dimensions shown in Figures 5 and 6 are still large enough to indicate the extent of the pneumatic system of the temporal bone. Figure 5 is a lateral view, corresponding to the view seen in Figures 1 and 2, and Figure 6 is a view corresponding to that seen in Figures 3 and 4. The lettering indicates the parts. Particular attention is called to Figure 6, where it can be seen that the plastic material extends over and around the petrous labyrinth. Apical cells shown in Figures 3 and 4 extend well internal to the labyrinth. The ends were, unfortunately, broken off in handling and they do not extend as far as the air cells. It must be remembered that what appears solid in the picture is actually air space in the bone.

It is comparatively easy to take roentgenograms of the cadaver. If the ear is normal, it is only necessary to puncture the drum membrane to inject the opaque solution. If the ear is diseased, pus has dried up and polyps have shrunken. In the living, as stated earlier in this paper, we can take

these roentgenograms only if the drum membrane is perforate. In that case there is pus and, often, polyps. The pus must be washed out from the deep recesses and the polyps must be shrunk. This is a time consuming and painstaking procedure. Nevertheless, the information gained is worth the trouble. Figures 7 and 8 are roentgenograms in the case of a man who had chronic purulent otitis media for many years. Polyps protruded from the external meatus. In spite of this handicap, the roentgenograms show a marked difference in the outline of the cells.

Not all cases are so difficult. But difficult or easy, it is necessary that fuller and more exact information be obtained.

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MULTIPLE MARCH FRACTURES*

THE STATICODYNAMIC EFFECT

By PERCY J. DELANO, M.D., *and* L.-V. CAPEK, M.D.
CHICAGO, ILLINOIS

THE term "march fracture" has emerged from the many names by which this clinical entity has been referred to, such as, "Fussgeschwulst," "pied forcé" "Deutschländer's Krankheit," "Marschgeschwulst," "pied débile," "pied de marche," "l'enflure du pied," "pied surchargé," and the like.

Around this group of descriptive terms were built up pathologic concepts equally contradictory, and intricately conceived. If one is interested in a very complete review of the growth of our understanding of march fracture, he should consult the excellent article by Meyerding and Pollock.[8]

In the present paper it is not intended to cover ground already so well explored, but before proceeding to the point of this article, it may be mentioned that Breithaupt thought the condition due to an inflammatory reaction in the tendon sheaths; Weisbach believed that it involved the ligaments rather than the tendons and called it "syndesmitis metatarsea"; Pauzat thought it due to the dorsal fold of the soldier's shoe, resulting in an "osteoplastic periostitis"; Poulet considered it a form of rheumatic diathesis; Deutschländer suggested a bacterial factor; Kirschner believed that it was induced by exhaustion of the muscles of the foot (and, incidentally, in 1905 decided that all cases were due to fracture, thus antedating his contemporaries by a considerable length of time in arriving at the truth of the matter).

The first roentgenogram depicting the condition is believed to have been taken by Stechow in 1897.

With further study of roentgenograms, the fracture line began to be described in some of them; then it began to be searched for in more of them; then, as roentgen technique improved, it began to be more frequently identified. One error in technique responsible for such lesions being overlooked is the practice of taking roentgenograms of the bones of the hands and feet using intensifying screens; such roentgenograms not only mask detail, but prevent the recognition of changes in osseous density which may occasionally give the clue to a disease process, such as a Sudeck's atrophy. In my observation, more than one fractured carpal navicular bone has passed unnoticed because the roentgenogram of the hand had been taken using intensifying screens.

As march fracture began finally to be more universally recognized in its true status, a rather voluminous literature filled with highly hypothetical etiologic concepts passed into oblivion. The situation is quite comparable to that obtaining in relation to "Kümmell's disease." During the years in which this interesting entity was regarded as a mystery, much discussion was carried on at various medical societies, but now that orthopedic surgeons are rather united in regarding "Kümmell's disease" as merely an overlooked compression fracture (due mostly to advances in roentgenographic technique), the subject has become neglected.

The question as to why march fractures occur in some individuals and not in others has swung the focus of inquiry closer to Morton's original concept of the "weak foot"; Morton and others have called attention to the short first metatarsal, the prevention of a proper weight-bearing thrust by the occurrence of certain types of sesamoids with the first metatarsal; Dodd,[1] quoting Shulte, thinks that protrusion of the second metatarsal is a predisposing

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Fig. 1. Simple fracture of first metatarsal.

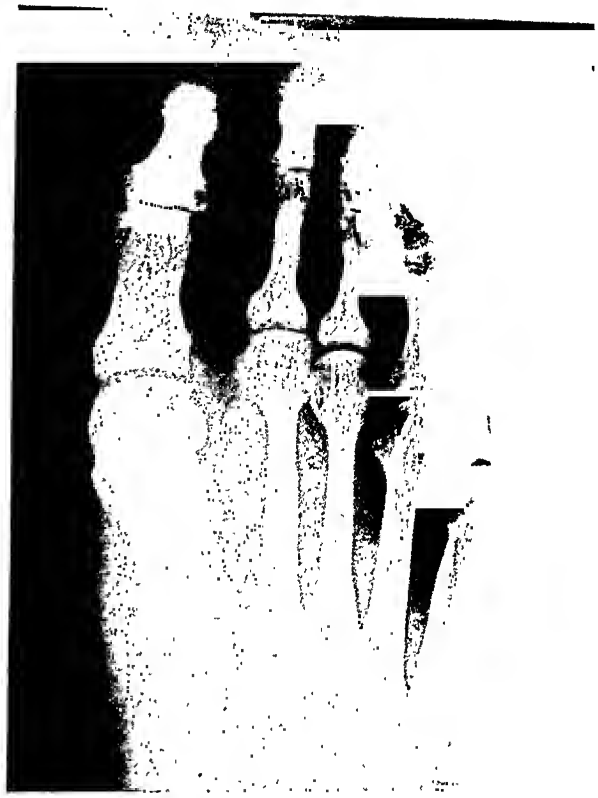

Fig. 2. Healing of the fracture shown in Figure 1; the patient is walking on the fracture, and the callus is exuberant.

Fig. 3. Continued weight bearing on the outer side of the foot, the patient trying to protect the injured first metatarsal, and a resultant march fracture of the second metatarsal.

Fig. 4. The patient continues to walk; now he has a second march fracture. Note also how this weight bearing continues to influence callus production in the first metatarsal.

factor; Sloane and Sloane[10] discuss the theory that compression of the blood supply by the interossei in a flat foot may predispose to the condition.

Hauser[5] in his textbook calls particular attention to metatarsus latus and pes valgoplanus as predisposing factors, and also mentions the fact that march fracture has been seen following radical operations for hallux valgus.

The case to be described here illustrates the manner in which two consecutive march fractures were produced in a foot considered normal before the occurrence of a simple fracture of the first metatarsal (the march fractures following the simple fracture).

This patient, injured while at work by dropping a heavy object on the great toe, gave evidence of an ordinary simple fracture of the first metatarsal (Fig. 1). The foot was placed in a cast, and the patient sent home. When returning for observation some days later, the rather exuberant callus about the healing fracture was commented upon, and the patient, who was suspected of not being cooperative, was cautioned again about weight bearing.

The patient returned at a later date with a still more diffuse layering of callus about the shaft of the fractured metatarsal, and, in addition, a fracture through the neck of the second metatarsal.

The cast was reapplied, and the cautions about weight bearing reiterated. Perhaps our presentation of the cause and effect in the condition was not clear, but at any rate the point of the matter seemed to have escaped our patient, for he returned at still a later date with a healing march fracture of the third metatarsal bone, which appeared quite comparable at that stage to the healing march fracture of the second metatarsal.

CONCLUSIONS

We believe that we have here illustrated the effect of an altered weight-bearing thrust: a foot appearing in no way abnormal before the occurrence of the first metatarsal fracture becomes the site of two march fractures because the patient, keeping his weight off the great toe and walking on the outside of his foot, so altered his weight-bearing thrust that two typical march fractures resulted.

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REFERENCES

1. Dodd, H. Pied forcé or march foot. *Brit. J. Surg.*, 1933–1934, *21*, 131–144.
2. Elward, J. F. March foot. Am. J. Roentgenol. & Rad. Theray, 1936, *36*, 188–193.
3. Furey, W. W. March foot or pied forcé. *Radiology*, 1936, *26*, 474–477.
4. Goldman, S. E. March foot, with fracture of metatarsal bone. *J. Bone & Joint Surg.*, 1928, *10*, 228–230.
5. Hauser, E. D. W. Diseases of the Foot. W. B. Saunders Co., Philadelphia, 1939, pp. 300–302.
6. Krause, G. R. March fracture. *Radiology*, 1942, *38*, 473–476.
7. Maseritz, I. H. March foot associated with undescribed changes of the internal cuneiform and metatarsal bones. *Arch. Surg.*, 1936, *32*, 49–64.
8. Meyerding, H. W., and Pollock, G. A. March fracture. *Surg., Gynec. & Obst.*, 1938, *67*, 234–242.
9. Monteith, W. B. R. Case of march foot (pied forcé) with signs of old and recent injury. *Brit. J. Surg.*, 1933–1934, *21*, 708.
10. Sloane, D., and Sloane, M. F. March foot. *Am. J. Surg.*, 1936, *31*, 167–169.
11. Speed, J. S., and Blake, T. H. March foot. *J. Bone & Joint Surg.*, 1933, *15*, 372–382.
12. Straus, F. H. Marching fractures of metatarsal bones, with report of the pathology. *Surg., Gynec. & Obst.*, 1932, *54*, 581–584.
13. Zeitlin, A. A., and Odessky, I. N. "Pied forcé" or "Deutschländer's disease." *Radiology*, 1935, *25*, 215–222.

CONTACT ROENTGEN THERAPY IN CANCER OF THE BLADDER*

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IN 1940 we described a method of treatment of cancer of the bladder by a combined surgical and radiation technique.[1] Briefly, the method consisted of marsupialization of the bladder with subsequent irradiation of the tumor by very low voltage roentgen rays with the tube in contact with the lesion. After a brief experience with this method, it was abandoned in favor of the simpler and more convenient plan of suprapubic cystotomy and direct irradiation of the tumor, with one or two re-openings of the bladder for further treatment.

Since we have now treated a total of 31 patients during a period of five years, it seems appropriate to review the results obtained and to attempt an evaluation of the method. We have in mind, moreover, the likelihood that, after the end of the present war, contact roentgen therapy will be in much more general use, and that our small experience in the treatment of cancer of the bladder should be available for the benefit of those who wish to undertake this method.

The technique which we have employed in all but four of the patients treated (i.e., those in whom the bladders were marsupialized) is fairly simple and, in the latter half of the series, became quite standardized. Under spinal anesthesia a classical suprapubic cystotomy is performed, exposing the tumor. After reduction of the mass to its base by fulguration, a dose of approximately 5,000 r is administered to the base of the tumor at a target-surface distance of 22 mm., the quality of the radiation being represented by a half-value layer of 1.0 mm. Al. The apparatus employed is the Philips-Metalix, operating at 50 kv., constant potential, and 2 ma. The roentgen tube is 23 inches long and slightly less than 2 inches in diameter at its active end. The anode is 2 cm. from the surface of the tube and the r afflux is 1,143 per minute with a filter of 1 mm. Al. The tube is entirely shockproof and may be held in the operator's hand, and its size and shape permits easy introduction through the cystotomy wound. After it has been well scrubbed with alcohol, it is placed in a sterile stockingette and covered with a sterile rubber sheath, under which conditions it may be introduced into the surgical field with impunity. Most cases treated had two cystotomies about one week apart and received a total dose of 10,000 r, although as much as 28,000 r has been given in twenty-two days.

In another communication[2] one of us has pointed out the danger inherent in what we might call the transliteration of the dosages named. It is very important to realize that it would be dangerous to administer a dose of 28,000 r under conditions other than those here described and that indeed it may be and likely is the case that the biological effect of the roentgen, with the very long wave length radiation employed, is quite different from that commonly experienced with more conventional radiation therapy.

Only moderate sloughing followed the treatment. In no case was there any serious hemorrhage, and there was no instance of perforation of the bladder or of fistula formation. There was no primary mortality.

Treatment has been limited to (a) tumors involving the trigone of the bladder and (*b*) tumors not more than 3 cm. in diameter. The size of the tumor is important, since those of more than 3 cm. diameter [illegible]

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be included in the irradiation field at contact, and since it is obviously impossible to employ multiple circular fields without either overlapping or leaving small irregular areas untreated. We have limited treatment to tumors involving the trigone because the alternative is total cystectomy with its high primary and secondary mortality. Neoplasms of the vault or lateral walls of the bladder may be treated by local resection and this, we believe, is preferable to radiation therapy when it can be performed. Rationalization of this combined surgical and radiation therapy procedure was as follows: Cancer of the bladder is, for a rather long time, a local disease, tending to metastasize only fairly late in its course. Most of these neoplasms are comparatively radiosensitive and the problem would seem to be simply the administration of a sufficiently large dose of radiation at the base of the tumor while avoiding irreparable injury to adjacent tissues. Suprapubic cystotomy and the use of the shockproof contact roentgen tube solves the problem of applying the irradiation to the tumor without loss of energy or the production of undesired irradiation effects in the overlying structures. Because of the very short target-surface distance (22 mm.), and the very low voltage (50 kv., constant potential) the depth doses are small, as shown in the accompanying table.

Circular field 3 cm. in diameter:

At 1 cm. depth	32%
2 cm. depth	13%
3 cm. depth	6.4%
4 cm. depth	3.6% surface dose

Thus protected by geometrical laws, very large doses may be administered without serious damage to underlying tissues.

Although little or no fault may be found with these assumptions, and in spite of the fact that the immediate results were impressive, a study of the 31 patients thus treated causes us to adopt a rather pessimistic attitude and serves to point the observation so frequently made that the local disappearance of a malignant tumor is not tantamount to its cure. Thirteen of the tumors treated were papillary carcinomas and 18 were infiltrating. Twenty-two of the tumors were graded and 9 were not classified as to degree of malignancy. Grade 3 tumors predominated with 11 tumors in this group. Six were in Grade 2, 3 in Grade 1 and 4 in Grade 4. All tumors treated involved some portion of the trigone or the bladder neck.

The number of treatments varied from one to eleven. Fifteen patients received two treatments each, 7 received only one treatment, 4 were treated three times, 1 had four treatments, and this group included all who underwent cystotomy for each treatment. Four patients (the first 4 treated) had marsupializations performed, after which 2 received ten and 2 eleven treatments. Those in the first group who received multiple treatments had them at approximately weekly intervals. Treatment of the marsupialized bladder occupied about three weeks, treatment being given on alternate days.

The total dose administered varied from a minimum of 5,148 r given in a single treatment to a maximum of 28,116 r, to those treated fractionally, all measurements being made in air. Fifteen patients had doses of about 10,000 r. Very large doses, approximating 28,000 r, were given to the 4 patients whose bladders were marsupialized.

Every patient treated had had a histopathological diagnosis, and in 20 of them a second biopsy was done at the final treatment. No cancer cells were found at the second biopsy in 13 of the 20 patients studied. The end-results achieved in the 31 patients treated are here summarized:

	Cases	Per Cent
Dead, but with no evidence of cancer at postmortem study	2	6.4
Dead, with cancer	10	32.3
Living, with cancer	10	32.3
Living, with no cancer	9	29.

Of those dead with cancer, 1 was a suicide whose treatment had not been concluded.

Of the 10 patients who died of cancer, 9 died in the first year after treatment, and 1

lived four years. There are 19 survivors and these have lived since treatment as follows:

	Cases
5 years......................	3
4 years......................	3
3 years......................	5
2 years......................	4
1 year.......................	4

The advantages of the combined surgical and low voltage contact roentgen irradiation method in the treatment of cancer of the bladder are: (1) low primary mortality (none in our series); (2) low secondary mortality; (3) complete exposure of the tumor, permitting biopsy for microscopic study, and fulguration; (4) comparative simplicity as contrasted with total cystectomy or radon seed implantation.

The disadvantages are: (1) multiple cystotomies, two or more in most instances; (2) rather long hospitalization (four to six weeks).

The results, to be properly evaluated, must be compared with those following curative efforts by surgery, i.e., total cystectomy, radon seed implantation, and high voltage external irradiation. A series of 21 patients had total cystectomy performed at the Memorial Hospital with 5 operative deaths, or a primary mortality of slightly more than 23 per cent. Eight of the survivors are living and apparently well, 5 of them for more than five years, 2 for eighteen months and 1 for thirty months.[3] At the same institution, 205 patients had radon seed implantation, 38 per cent were said to be "controlled," and 19 per cent were free from cancer five or more years after treatment.[4] As to external irradiation, it is unlikely that many five year cures are effected with 200 kv. irradiation. Perhaps roentgen rays produced at higher voltages will offer hope of improved results, although the few statistics available do not offer much encouragement. Colby and Schulz[5] report 101 cases of cancer of the bladder treated with supervoltage roentgen therapy. Of this series 33 per cent have survived from one to five years with carcinoma and 12 per cent have survived one to five years without disease.

In conclusion, we may say that, having in mind the disadvantages and limitations of the combined surgical and low voltage contact roentgen irradiation technique, it is a useful addition to the few methods available for treatment of cancer involving the bladder trigone. We believe that its use should be limited entirely to the treatment of tumors not more than 3 cm. in diameter which involve the trigone or the bladder neck. Under these conditions, the results are probably at least as good as those obtained by any other method and, in view of the low primary and secondary mortality, the method is to be preferred to total cystectomy.

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REFERENCES

1. Goin, L. S., and Hoffman, E. F. Use of intravesical low-voltage contact roentgen irradiation in cancer of the bladder. *Radiology*, 1941, *37*, 545–549.
2. Goin, L. S. Low-voltage contact irradiation therapy; further experience. *Radiology*, 1944, *42*, 241–245.
3. Pack, G. T., and Livingston, E. M., Editors. Treatment of Cancer and Allied Diseases. Paul B. Hoeber, Inc., New York, 1940, Vol. III, pp. 1857.
4. *Idem.*, p. 1935.
5. Colby, F. H., and Schulz, M. D. Review of carcinoma of bladder treated by supervoltage x-rays over a 5-year period. *Radiology*, 1943, *41*, 371–377.

AN ANALYSIS OF THE PHYSICAL FACTORS CONTROLLING THE DIAGNOSTIC QUALITY OF ROENTGEN IMAGES*

PART II. MAXIMUM RESOLVING POWER AND RESOLUTION COEFFICIENT

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IN THE first of this series of articles,‡ the physical factors affecting the diagnostic quality of roentgenographic films and roentgenoscopic screens were analyzed. Beginning with the premise that the interpretability of a roentgen image is closely related to the ability of the recording film or screen to register detail, it was shown that diagnostic quality is dependent on the maximum resolving power of the roentgenographic film or roentgenoscopic screen, on a relatively minor factor called the resolution coefficient, on the contrast which the various roentgen images exhibit and the unsharpnesses of the images. It was further pointed out that the relationship between these several factors is given by the equation

$$R=R_m(1-e^{-aC})(U_f/U_t) \qquad (1a)$$

where R is the resolving power or ability of the roentgenographic film or roentgenoscopic screen to record detail,

- R_m is the maximum resolving power of the film or screen,
- a is the resolution coefficient,
- C is the contrast between an image and its surrounding field,
- e is the Naperian base,
- U_f is the inherent unsharpness of the film or screen and
- U_t is the overall unsharpness with which an image is recorded (inherent unsharpness and extraneous unsharpness such as that contributed by anatomical movement and an excessively large roentgen tube target collectively).

Equation (1a) is valid for all contrast levels. For images of low contrast, however, the relationship may be expressed more simply by the equation

$$R=R_m aC(U_f/U_t) \qquad (1b)$$

In this communication, the significance of the maximum resolving power and resolution coefficient of a roentgenographic film or roentgenoscopic screen will be discussed. Methods for measuring these parameters as well as quantitative data on representative commercial films and screens will be included.

Resolving power is a measure of the ability of a photosensitive material (e.g. photographic film, roentgenographic film, fluorescent screen, etc.) to record detail. It is customarily determined by projecting on the material under test an image of a suitable object whose pattern is relatively difficult to reproduce and whose pattern may be varied in a quantitative manner from a fine to a coarse configuration.

In photography the test-object usually employed is a black and white, high contrast, line drawing similar to that shown in Figure 1, Part 1, of this series. The width of the lines is customarily equal to the width of the spaces although for some work this practice is not always retained. The drawing is photographed on the film under test, care being taken to use a lens capable of resolution considerably better than that of the film. The film usually experiences little difficulty in reproducing the coarser patterns. As one proceeds to the finer con-

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‡ Morgan, R. H. An analysis of the physical factors controlling the diagnostic quality of roentgen images. Part 1. Introduction. Am. J. Roentgenol. & Rad. Therapy, August, 1945, *54*, 128–135.

figurations, however, the patterns eventually become so small that the lines fuse and appear as a homogeneous density. The greatest number of lines per millimeter which can be distinguished in the developed and processed film constitutes the film's resolving power.

The methods of measuring the resolving power of photographic materials have become well standardized. Normally, a high contrast test-object is employed and accordingly the determinations indicate maximum resolving power (see equation (1)). Photographic manuals, listing the resolving powers of various photographic materials, however, usually omit the qualifying term, "maximum," it being taken for granted that the reader recognizes the omission.

Although methods for measuring the resolving powers of photographic materials are well established such is not the case for roentgenographic films and fluorescent screens. The development of a suitable test-object appears to be the principal difficulty which has impeded progress in this direction. It will be obvious that the test-objects which have proved so successful in photography are useless in roentgen applications. It is theoretically possible to construct a test-object composed of alternating laminations of lead foil and of paper (or some other radiolucent material) which when interposed in a roentgen beam will produce on a roentgenographic film or fluorescent screen a linear image similar to those produced by photographic test-objects on photographic film. Furthermore, by varying the thickness of the laminations, the pattern could be varied quantitatively from a fine to a coarse configuration. In practice, however, such test-objects are extremely difficult to construct and use. If they are not precisely aligned with the roentgen beam, the results obtained are unreliable since slight maladjustment of a few minutes of a degree will cause adjacent laminations to overlap in the beam.

Before discussing other attempts to make suitable test-objects for roentgen measurements, it might be well to consider briefly the criteria which must be fulfilled by a standard test-object for use in measuring the resolving power of a photosensitive material. First, the object must present a relatively intricate pattern so that the ability of the material to record detail is adequately tested. Second, it must be possible to vary, quantitatively, the size of its pattern, retaining at the same time an identical configuration; third, the object must be easily reproducible. In addition to these, there are certain other criteria which must be fulfilled for roentgen experiments: Alignment with the roentgen beam must be easily obtained and, other things being equal, measurements must be independent of the quality of the roentgen radiation.

It is evident that although a linear test-object has been found suitable in photography, it is not essential that such a pattern be retained in roentgenography or roentgenoscopy. Realizing this, White[1] recently developed a test-object which when properly designed appears to fulfill all of the above criteria. The object consists of wire ranging in size from 0.08 to 4 mm. in diameter wound on mandrils of convenient diameter (e.g., 2 to 5 mm.). Approximately 10 to 15 turns of each size of wire are employed, and are wound with adjacent turns in close apposition. Eighteen sizes of wire within the limits of diameter stated provide a sufficient number of steps to permit a satisfactorily precise evaluation of the resolving power of any roentgenographic film exposed with intensifying screens and of any roentgenoscopic screen now available. Test-objects with finer wire are now being constructed for the testing of films exposed to roentgen radiation directly. A photograph of a portion of the wire-wound test-object is shown in Figure 1*a*. Figure 1*b* illustrates a roentgenogram of this same segment. It will be observed that the object produces a serrated pattern, a configuration somewhat more difficult to reproduce than the linear photographic pattern.* The prac-

* This is borne out by the fact that the resolving [illegible] several photographic films measured in this laboratory [illegible] serrated test-object identical in configuration to the [illegible]

tice has been adopted in this laboratory to specify resolving-power measurements made with this test-object in terms of serrations per millimeter, the resolving power of a material being the largest number of serrations per millimeter which can be distinguished.

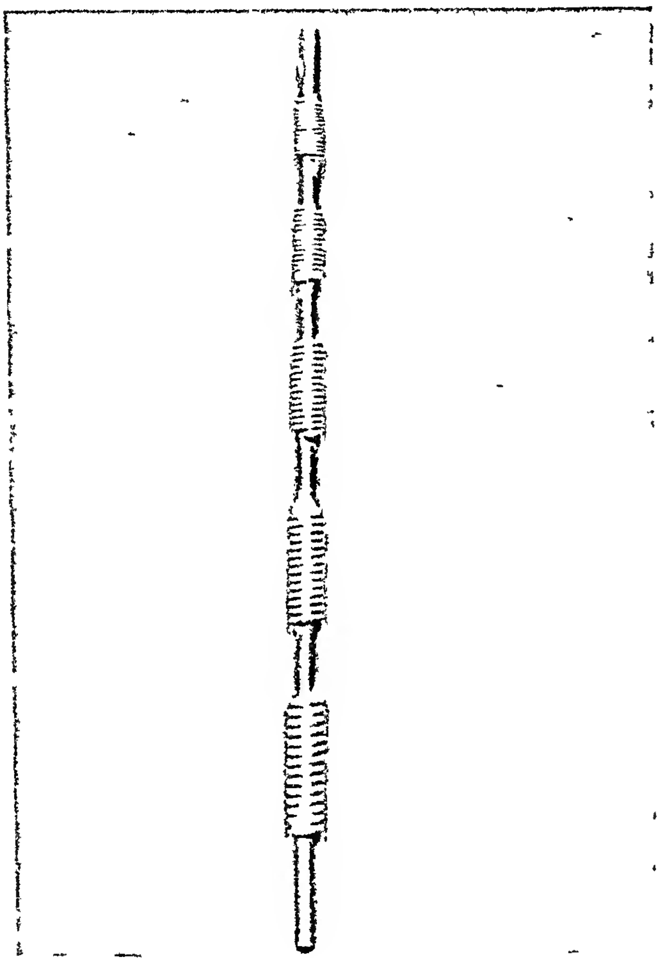

Fig. 1*a*. Wire-wound test-object suitable for measuring the resolving power of roentgen materials.

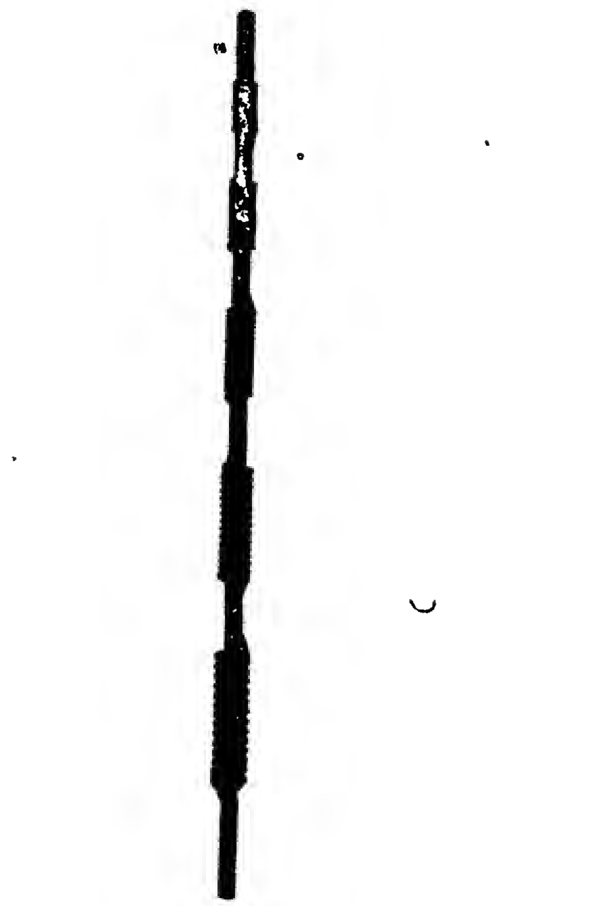

Fig. 1*b*. Roentgenogram of test-object, shown in Figure 1*a*, illustrating serrated pattern.

The wire-wound test-object is easily constructed and simple to align with the roentgen beam. Furthermore, when silver wire is employed, results are independent of roentgen quality over a range extending from a half-value layer of 0.33 mm. Al to a half-value layer of 9.0 mm. Al. This embraces the range of quality usually employed in diagnostic roentgenology. This independence of quality is well shown in Figure 2 where the resolving power of Eastman Blue Brand film exposed with a

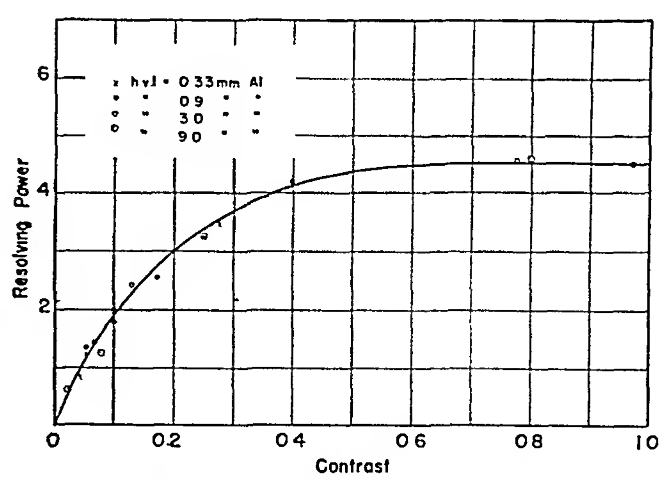

Fig. 2. Relationship between resolving power and contrast for Eastman Blue Brand film exposed with a Buck front type intensifying screen for four qualities of radiation. The manner in which the experimentally observed values fall closely along a common locus indicates that the test-object performance is independent of roentgen quality.

the wire-wound test-object are approximately 30 per cent less than those measured with the conventional line drawing. This relationship was also found to hold for measurements of visual resolution.

front type Buck intensifying screen is plotted over a wide range of contrast for four qualities of exposing radiation. It will be observed that the various points fall, within experimental error, on a common locus. A front screen only was used in conducting this determination because the resolving power of such a film-screen combination should remain constant regardless of the quality of the exposing radiation. As will be shown presently, the resolving powers of films exposed in the conventional manner with front and back intensifying screens often vary considerably with roentgen quality, principally due to differences in the contribution to film blackening by the dissimilar front and back screens.

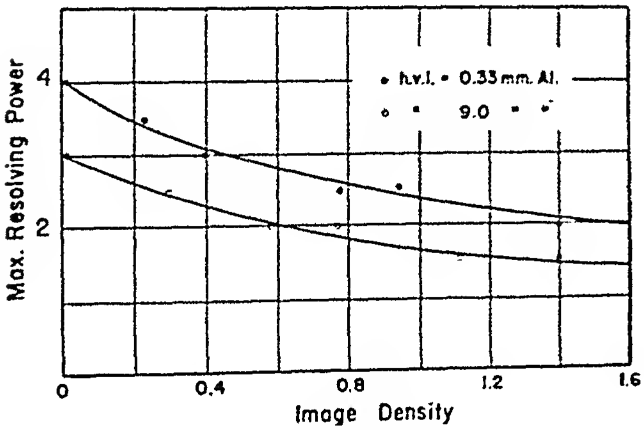

FIG. 3. Maximum resolving power of Eastman Blue Brand film exposed with Buck X-tra Speed intensifying screens plotted as function of image density for two qualities of radiation. Observe how resolution diminishes with increasing image density; also how resolution diminishes with increasing hardness of the radiation. In Buck X-tra Speed screens the front screen is a fine-grain type, the back screen a relatively coarse-grain type. When the radiation is of long wavelength the front screen contributes predominantly to film blackening because little radiation penetrates to the back screen. Consequently resolution is high (fine-grained front screen). When the radiation is of short wavelength much of the film blackening is contributed by the inherently brighter back screen because the radiation now is able to penetrate the front screen. Consequently resolution is low (coarse-grained back screen).

The resolving powers of four brands of roentgenographic film, exposed in combination with nine brands of intensifying screens have been determined with the wire-wound test-object. Two brands of fluoroscopic screens and two photofluorographic assemblies have also been examined. The roentgenographic and photofluorographic exposures were made over an image-background contrast range extending from a density of zero to a density of 2.0, a range more than sufficient with which to evaluate the maximum resolving power of the material under test.

The various determinations were made simply by placing the test-object over the cassette containing the film or film-screen combination under examination and giving sufficient exposure to produce the desired contrast. The experiments were conducted with four qualities of radiation having half-value layers of 0.33, 0.9, 3.0 and 9.0 mm. of aluminum respectively.

Because of the high absorption of the silver test-object, the image density of the various films was essentially zero. Since resolving power might be a function of image density, the determinations were repeated after the film-screen combination had been given sufficient over-all pre-exposure (i.e., with no test-object in place) to produce final image-densities of approximately 0.5, 1.0, 1.5 and 2.0. The many films were processed under as closely identical conditions as possible in a pictol hydroquinone developer at a temperature of 65° F. and with a developing time of five minutes. The results of these experiments are recorded in Figure 3 and in Tables I and II.

In Figure 3, the maximum resolving power (R_m) of a typical film-screen combination is plotted as a function of image density for the two extreme qualities of radiation studied. It will be observed that R_m is greatest when the image density is zero and gradually decreases when this parameter increases. All of the films and film-screen combinations studied exhibited this general characteristic, [illegible] materials demonstrating [illegible] than others. It is [illegible] the particular film-screen [illegible] illustrated in Figure 3, R_m [illegible]

siderably when the quality of the exposing radiation becomes harder. This effect, as one might expect, is always particularly pronounced when exposures are made with front and back intensifying screens that are markedly dissimilar and is absent in photofluorographic films.

In Table I are tabulated the maximum resolving powers of four commercial brands of roentgenographic films exposed with nine types of intensifying screens. The screens marked with a single asterisk are so-called "high speed screens," those marked with a double asterisk, "medium speed screens" and those marked with a triple asterisk, "high definition screens." Data

TABLE I

MAXIMUM RESOLVING POWERS (SERRATIONS PER MILLIMETER) OF VARIOUS FILM-SCREEN COMBINATIONS NOW COMMERCIALLY AVAILABLE IN THE UNITED STATES

Brand of Intensifying Screen	Brand of Film			
	A	B	C	D
I*	3.0 2.5	3.0 2.5	3.0 2.5	3.0 2.5
II**	4.0 3.5	4.0 3.5	4.0 3.5	4.0 3.5
III***	6.0 6.0	6.0 6.0	6.0 6.0	6.0 6.0
IV*	4.0 3.0	4.0 3.0	4.0 3.0	4.0 3.0
V**	4.0 3.5	4.0 3.5	4.0 3.5	4.0 3.5
VI***	5.0 5.0	5.0 5.0	5.0 5.0	5.0 5.0
VII*	3.5 3.0	3.5 3.0	3.5 3.0	3.5 3.0
VIII**	4.0 3.5	4.0 3.5	4.0 3.5	4.0 3.5
IX***	4.0 3.5	4.0 3.5	4.0 3.5	4.0 3.5

* "High speed screens."
** "Medium speed screens."
*** "High definition screens."

for photofluorographic films are listed in Table II. It will be observed that two figures are listed for the various film-screen combinations. These data indicate the limits of maximum resolving power over the range of quality studied. All of the

TABLE II

MAXIMUM RESOLVING POWERS (SERRATIONS PER MILLIMETER) OF VARIOUS PHOTOFLUOROGRAPHIC FILMS

Film	Resolving Power
35 mm.	0.75
70 mm.	1.25
4×5 inch	1.50

Eastman Photofluorographic film (an orthochromatic or blue, green and yellow sensitive emulsion) was used for the 35 mm. and 70 mm. exposures. Single coated Eastman Blue Brand film (blue sensitive emulsion) was used for the 4×5 inch exposure.

figures for the roentgenographic materials were determined from films having an image density of zero; approximate values at other image densities may be calculated with little difficulty from Figure 3.

Attention is directed to the independence of resolving power and the brand of roentgenographic film. Apparently the resolution of an intensifying screen is so much lower than that of a film that the resolving power of the latter plays very little part in determining the resolution of the film-screen combination.

The experiments on the fluorescent screens (type "B" and photoroentgen) were performed by making contact exposures with photofluorographic film. They have no direct significance relative to what may be seen with these screens roentgenoscopically, but are useful, as will be shown presently, in studying certain problems in photofluorography. Visual data on roentgenoscopic screens are now in preparation and will be reported in a later communication.

The resolving power of a photosensitive material is a function of several factors including the sharpness with which an image is recorded and the granularity of the film. Lowry[2] and Goetz, Gould and Dember[3]

have shown that granularity increases with film-density. In Part VI of this series it will be shown that sharpness decreases with film-density. In view of these facts it is not surprising that resolving power also decreases with film-density.

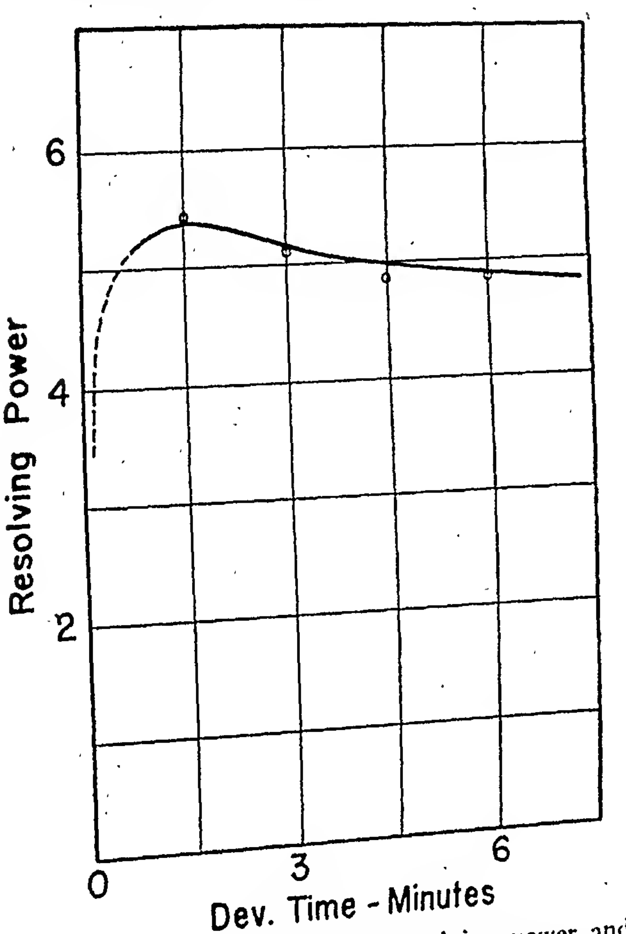

Fig. 4. Relationship between resolving power and developing time for a typical roentgenographic film-screen combination.

There is considerable experimental evidence to indicate that maximum resolving power is influenced by the process of development. Sandvik[4] and Ronchi[5] found that as development progresses, resolving power rises rapidly to a maximum, diminishes somewhat, and then remains essentially constant. This characteristic appears to be common to most photographic emulsions. Several roentgenographic films and film-screen combinations have been examined in this laboratory to determine the effect of development on resolution. The relationship between resolving power and time of development for a typical roentgenographic film-screen combination is shown in Figure 4. The curve is similar in configuration to those obtained by Sandvik and Ronchi. It should be pointed out here that although maximum resolving power does not change appreciably after a short development, the inherent contrast factor of a film rises rapidly as development progresses. The observed resolving power for images of low contrast, as indicated by equation (1b), therefore diminishes rapidly with underdevelopment.

At one time, developer composition was thought to have a marked effect on resolving power. Experiments by Ross,[3] however, do not seem to justify this opinion. The influence of developer composition on the resolution of roentgenographic materials was not thoroughly studied in this investigation, but some evidence was obtained which tends to indicate that resolution is not greatly affected by developing parameters.

The data for the photofluorographic materials listed in Table II require further discussion. These values do not represent the maximum number of serrations per millimeter of film that can be visualized but, instead, indicate the maximum number of serrations per millimeter observed when the film is enlarged or magnified to a point where the image of the test-object appearing in the photofluorogram is identical in size to the object itself. This method of notation was adopted so that the photofluorographic and roentgenographic data might be comparable. The maximum resolving powers of 35 mm., 70 mm., and 4×5 inch photofluorograms, measured in the conventional way, are 9.0, 7.5 and [illegible] serrations per millimeter respectively. Since the images appearing in the several films constitute minifications of approximately 12.5, 6.25 and 3.7 times respectively, the effective resolving powers fall to the values appearing in Table II.

It is evident that the effective resolving powers of photofluorographic materials are rather low. The cause of this [illegible] can be attributed to a number of [illegible]. It was pointed out in Part [illegible] that resolving power may [illegible]

duced when conditions which promote unsharpness of the roentgenographic images are present. In photofluorography, three such conditions exist. Some unsharpness is produced by the fluorescent screen; more is contributed by the lens of the photofluorographic camera and finally the clarity of the image is further reduced by the inherent unsharpness of the film. In general, when several factors which produce unsharpness operate collectively, the overall or total unsharpness is the sum of the individual factors;* that is,

$$U_t = U_1 + U_2 + \cdots U_n \qquad (2)$$

Since resolving power tends to bear an inverse relationships to unsharpness (equation (12), Part I), the resolving power of the photofluorographic process may be expected to approximate

$$\frac{1}{R_{pf}} = \frac{1}{R_s} + \frac{1}{R_e} + \frac{1}{R_f} \qquad (3)$$

where R_{pf} is the resolving power of the photofluorographic process;
R_s is the resolving power of the fluorescent screen;
R_e is the resolving power of the lens, and
R_f is the inherent resolving power of the photofluorographic film.

The resolving power of the fluorescent screens customarily employed in photofluorography is 2.25 serrations per millimeter. The resolving powers of conventional photofluorographic lenses and film are each approximately 50 lines per millimeter or 35 serrations per millimeter. Values of lens and film resolution, however, cannot be considered in relation to that of the screen until account is taken of the amount of magnification necessary to enlarge the film to screen size. With such enlargement, the resolving powers for lenses and films become 3.0, 6.0 and 10 serrations per millimeter for 35 mm., 70 mm. and 4×5 inch films respectively. Substituting these values in equation (3) the predicted resolving powers of the various photofluorographic processes are 0.9 ser./mm. (35 mm. film); 1.25 ser./mm. (70 mm. film); and 1.5 ser./mm. (4×5 inch film). It is interesting that the predicted values fall close to the observed values listed in Table II.

It is noteworthy that in the case of 35 mm. photofluorography the values of the various factors in equation (3) are closely similar. Accordingly, although some increase in resolving power could be achieved by improving the characteristics of either the screen, lens or film, such an increase would not be great until all three were appreciably improved. It is not likely, therefore, that any significant increase in the resolution of 35 mm. photofluorograms will occur for some time. In the case of 70 mm. and 4×5 inch photofluorography, however, the resolution of the screen is considerably below that of the lens and that of the film. Thus, although no large increase in resolving power could be realized by improving the latter two components, a sizable increase could be accomplished by improving the properties of the former. Indeed, by doubling screen resolution, the resolving powers of 70 mm. and 4×5 inch photofluorograms would be raised to 1.8 and 2.3 ser./mm. respectively; that is, increases of 50 per cent and over. It is not known what possibilities exist for improving photofluorographic screens. However, efforts to enhance the quality of 70 mm. and 4×5 inch photofluorograms should be centered on this phase of the problem.

Finally, let us direct our attention to a discussion of the resolution coefficient, a, a factor which plays an important rôle in determining the resolving power of roentgen images at low contrast levels. Referring to equation (1a) it is evident that a may be determined by measuring the slope (R/C) of the resolving power versus contrast curve at zero contrast and dividing the result by the value of the film's maximum resolving power, R_m. Values of a for present-day roentgen materials fall within a rela-

* This relationship is valid only under limited circumstances. It will be discussed at considerable length in Part VI of this series.

tively narrow range in the vicinity of 5.0. They appear to be independent of the quality of the exposing radiation and are only slightly affected by the density of the roentgenographic image.

Little is known regarding the factors which govern the resolution coefficient of a photosensitive material. Since it achieves its principal significance at low contrast levels, it is possible that its value is a function of the grain-size distribution of the particles which comprise the material and of the statistical fluctuation in the intensity of the exposing radiation. It is interesting that when visual resolution is tested, values of a, exceeding 9.5 have been obtained under conditions of maximum visual acuity. Sandvik[4] when testing several photographic materials obtained values of approximately 2.2, on the other hand. A great deal more must be known of the fundamental relationships between resolution and contrast before the significance of the resolution coefficient can be fully understood. This of course need not lessen the usefulness of experimentally derived values of the coefficient in the prediction of the resolution of roentgenographic films and roentgenoscopic screens at various contrast levels.

REFERENCES

1. White, D. R. Personal communication.
2. Lowry, E. M. Instrument for the measurement of the graininess of photographic materials. *J. Optic. Soc. America*, 1936, *26*, 65.
3. Goetz, A., Gould, W. O., and Dember, A. Objective measurement of graininess of photographic emulsions. *J. Soc. Motion Pic. Eng.*, 1940, *34*, 279.
4. Sandvik, O. Dependence of resolving power of a photographic material upon the contrast of the object. *Phot. J.*, 1928, *68*, 313.
5. Ronchi, V. Ueber das Auflösungsvermögen von photographischen Schichten. *Ztschr. f. wiss. Photograph., Photophys. u. Photochem.*, 1940, *39*, 1.
6. Ross, F. E. Physics of the developed photographic image. Monographs on the Theory of Photography from the Research Laboratory of the Eastman Kodak Co., No. 5, Rochester, N. Y., 1924.

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NOTES ON THE USE OF PROTECTIVE GLASS IN PHOTOFLUOROGRAPHIC EQUIPMENT*

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WASHINGTON, D. C.

IT HAS been standard practice in the construction of photofluorographic equipment to place a sheet of plate or lead glass† between the fluorescent screen and the photographic camera. Dust, thereby, is prevented from falling on the screen and, in the case of lead glass, the photographic lens and film magazine are protected from excessive radiation exposure. Conventionally, the glass is placed either in direct contact with the screen, thereby providing some support to this structure, or an inch or two toward the photographic camera. A schematic diagram of the latter arrangement is shown in Figure 1.

Although a number of worth while purposes is served by the glass, its use is attended by several disadvantages. First, it complicates the optical system between the screen and photofluorographic film, thereby causing some reduction in the clarity or detail with which the various fluorescent images are recorded. Furthermore, it reflects a portion of the light emitted by the screen. This reflected light is diffusely distributed over the screen surface, thereby fogging the images appearing therein and reducing their contrast. In addition, the glass adds materially to the weight of the photofluorograph, is relatively fragile and therefore subject to damage under the rigorous operating conditions of photofluorography and, finally, reduces the intensity of the light reaching the photographic camera and accordingly prolongs the roentgen exposure to some degree.

The extent to which the disadvantages of the glass counteract the benefits has been the cause of much speculation in recent years. The matter has been currently under investigation in this laboratory and it is hoped that the results obtained will provide a satisfactory answer to the question.

The effect of the protective glass on the clarity or detail with which photofluorographic images are recorded was studied by measuring the resolving power of

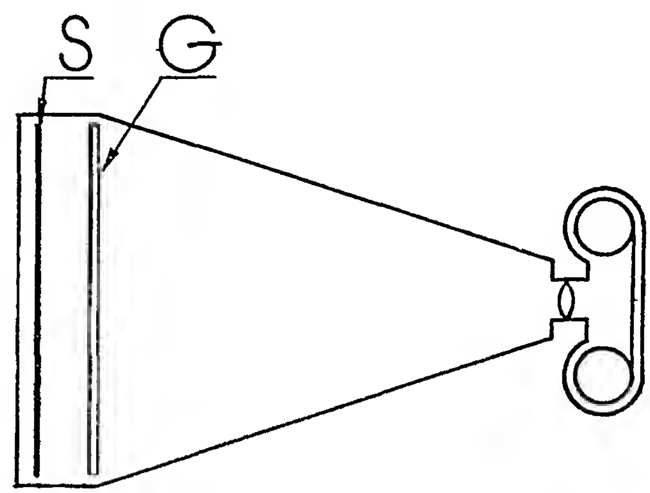

Fig. 1. Schematic diagram of typical photofluorograph illustrating relationship of fluorescent screen, *S*, and protective glass, *G*.

photofluorographic film in the presence and in the absence of the glass. These measurements were carried out by photofluorographing on the film under test a wire-wound test-object similar to that recently described by one of the authors.[1,2] This object produces on the film a series of serrated patterns ranging from a fine to a coarse configuration. In 35 mm. photofluorography the film was able to resolve 0.75 serration per millimeter when the glass was present and 1.0 serration per millimeter when it was absent. Thus the removal of the glass improved the clarity of reproduction by 33 per cent. In 70 mm. photofluorography the results were less

* From the Radiology Section, Tuberculosis Control Division, U. S. Public Health Service.

† Plate glass is used in the General Electric Photo-Roentgen unit, lead glass in the Westinghouse Photofluorographic unit.

striking. In the presence of the glass, the resolution was 1.25 serrations per millimeter and in its absence, 1.37 serrations per millimeter, or a difference of 10 per cent. The relatively small effect in this instance is likely due to the fact that the influence of the optical system on clarity of reproduction is not as great in 70 mm. as in 35 mm. photofluorography.[2] For similar reasons the difference is also probably small in 4×5 inch photoroentgenography.

The effect of protective glass on the contrast of photofluorographic images may be directly ascribed to reflectance. Some of the fluorescent light radiated by the screen is reflected by the glass and distributed over the screen surface in such a way as to produce a fogging of the included images. The effect is particularly severe when the glass is located some distance from the screen for under this circumstance the radiation is more widely dispersed than when the glass is in contact with the fluorescent material. Furthermore, since reflection occurs at both surfaces of the glass, the reflectance is effectively twice as great when glass and screen are separated as when in contact, for in the latter instance light reflected at the surface in apposition with the screen merely returns to the various crystals from which it originated and is not distributed in a manner which would lead to a reduction in contrast.

The relationship between reflectance and contrast is a simple one. The contrast of a fluorescent image is equal to the difference between the logarithm of the screen brightness at the locus of the image and the logarithm of the screen brightness in the surrounding field. Therefore, if I_i and I_b are the screen brightnesses induced by roentgen radiation in the image and in the surround respectively, the contrast in the absence of reflection is

$$C=\log I_i-\log I_b \qquad (1)$$

Now, if extraneous light such as that reflected from a sheet of protective glass were to fall on the screen, the brightnesses of the image and of the surround would be increased and the contrast changed to a value given by the equation

$$C=\log (I_i+I_r)-\log (I_i+I_r) \qquad (2)$$

where I_r is the intensity of the reflected light falling on the screen.

The values of the several factors appearing in equations (1) and (2) are dependent on a variety of factors including the location of the protective glass. When screen and glass are separated a distance of 2 inches, photometric measurements indicate that the intensity of the reflected radiation returning to the screen is approximately 4 per cent of the brightest significant chest image when the subject under examination covers the entire screen. It is higher when small individuals are photofluorographed due to the high intensity of the light emitted from the uncovered portions of the screen. When this datum is substituted in equations (1) and (2), the loss in contrast suffered by a low contrast fluorescent image of any brightness level less than that of the brightest significant image within the chest silhouette may be easily calculated. This relationship between loss of contrast and screen brightness is illustrated graphically in Figure 2.

It is evident that images of low light intensity such as those of the hilar regions of the chest and of many parenchymal pathological processes* suffer a loss in contrast approaching 20 to 25 per cent. Although this is relatively small it is nevertheless undesirable.

When the protective glass is in contact with the screen, the reflectance cannot be specified so easily as in the case when the two structures are separated. Since the apposition of screen and glass prevents wide diffusion of the reflected light the reflectance varies from point to point over the screen surface. Its nominal value at any location is 4 to 5 per cent of the screen brightness induced by roentgen radiation at that location. Occasionally when a

* The brightness of the screen within the images of the hilar regions is usually 10 to 20 per cent of the brightness of the [illegible] lung fields.

series of small low intensity images is located in a bright surround the ratio of reflectance to image intensity rises to rather high levels. Since this situation occurs infrequently, however, the loss in contrast when glass and screen are in contact is usually not greater than 5 to 10 per cent.

The increase in roentgen exposure observed when a sheet of glass is placed between the fluorescent screen and photographic camera is caused by a part of the light emitted from the screen being absorbed or reflected by the glass and thereby prevented from reaching the camera. The effect is mainly one of absorption, only a small portion of the reflected light being lost since most of it returns to the screen where it is redirected toward the camera.

In one photofluorograph that was studied in this laboratory it was necessary to increase the roentgen exposure 8 per cent* when lead glass 0.25 inch in thickness was placed between the fluorescent screen and photographic camera. Undoubtedly there are samples of such glass where a greater increase is necessary. When plate glass was investigated the absorption was so minimal that no increase in exposure was required.

From the foregoing it is evident that the disadvantages of protective glass in photofluorographic equipment depend on the construction and type of apparatus. A significant loss of clarity is observed in 35 mm. film. Loss of contrast is especially pronounced when the protective glass and screen are separated. When lead glass is employed an increase in roentgen exposure is necessary to compensate for the light absorbed by the glass.

The benefits derived from the use of protective glass are, as previously pointed out, the prevention of damage to the fluorescent screen by dust and accident and, in the case of lead glass, the protection of the photographic lens and film magazine from excessive radiation exposure. In regard to the effect of roentgen radiation on the photographic lens, it is known that large quantities of radiation discolor the glass and reduce its transmission. Furthermore, instances have been reported[3] where the cementing materials of the lens have become cloudy, thereby seriously affecting lens performance. These effects, however, have been observed only under unusual circumstances and there is considerable doubt that changes would occur under photofluorographic conditions in the absence of protection.

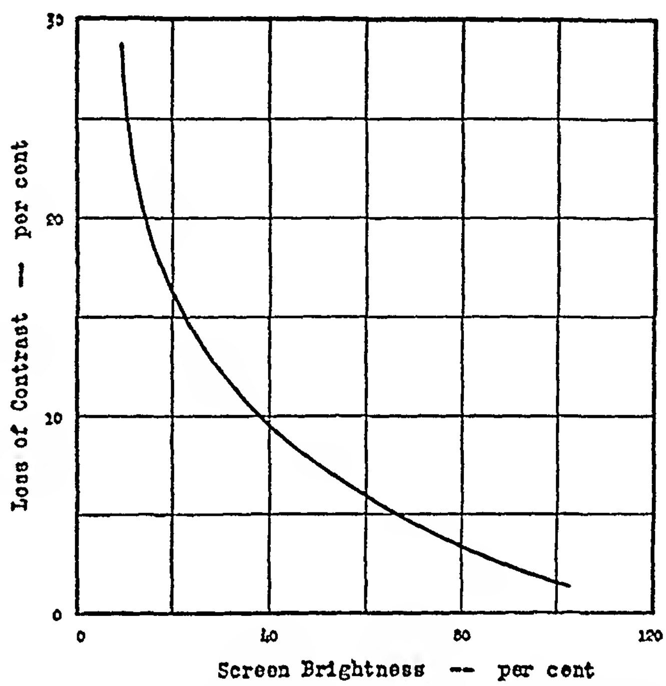

Fig. 2. Loss of contrast suffered by fluorescent images of various brightness levels as a result of reflection from a sheet of protective glass located 2 inches in front of a photofluorograph's fluorescent screen. One hundred per cent brightness level corresponds to the illumination of the brightest significant image within the chest silhouette. Data are based on an average reflectance of 4 per cent of the 100 per cent brightness level, a value consistent with experimental observation.

Radiation measurements conducted in this laboratory on a photofluorograph from which the lead glass had been removed revealed that under average conditions (i.e., a subject 20 cm. in thickness photofluorographed with the roentgen machine operating at 90 kv. (peak) and 200 ma. and with

* A perusal of the literature reveals a relatively wide variation in the absorption data for lead glass. This situation is probably the result of differences in the characteristics of the lead glass studied and failure of some workers to separate the effects of absorption and reflectance.

an exposure time of 0.2 sec.) 0.001 r per exposure is received at the lens site. Since the normal life of a photofluorograph is approximately 500,000 exposures, an unprotected lens, therefore, may be expected to receive 500 r over its period of service. Following these measurements an Eastman Ektar lens similar to those employed in 35 mm. and 70 mm. photofluorography was subjected to a series of graded exposures totalling over 1,000 r. No evidence of lens discoloration or clouding occurred and determinations of relative lens speed (reciprocal of the exposure required to produce a film density of 1.5) made during the test revealed no loss of transmission. In Figure 3, these determinations are plotted against the number of equivalent exposures received by the lens, one equivalent exposure equalling 0.001 r. In these experiments the quality of the roentgen radiation employed was identical to that encountered in photofluorographic practice (half-value layer = 6 mm. of aluminum). It is evident that protection of the photographic lens is quite unnecessary.

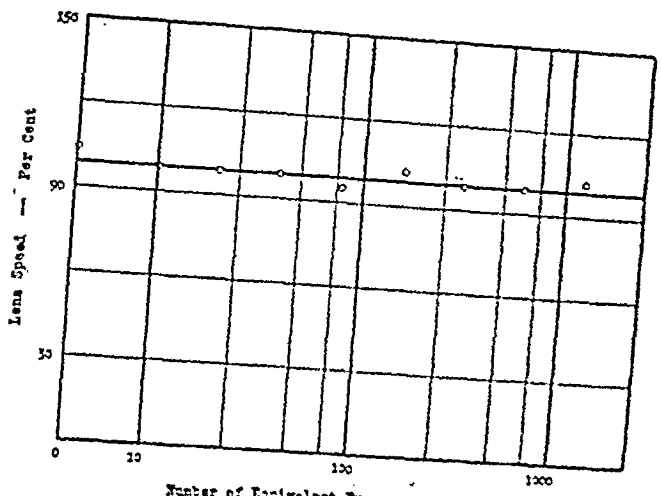

FIG. 3. *Speed of an Eastman Ektar f/1.5 lens plotted as a function of the number of equivalent exposures to which the lens was subjected in test to determine effect of exposure to roentgen radiation. One equivalent exposure was 0.001 r, the radiation to which the lens would be subjected in a photofluorograph without lead glass protection during the exposure of an average photofluorogram.*

In regard to the film magazine, protection is particularly important when a roll-film camera is employed. In 35 mm. photofluorography over 700 exposures and in 70 mm. photofluorography over 350 exposures are normally made on a 100 foot roll and the film magazine is therefore subjected to 0.70 r and 0.35 r respectively during the time these exposures are made if no protection is provided. Such a quantity of radiation is sufficient to cause considerable fogging of the film. Although adequate protection may be obtained by the use of lead glass placed between the fluorescent screen and photographic camera it may be achieved equally well by lining the film magazine with lead foil.

The need for protection of the photofluorographic screen against dust and accident does not appear to be very striking. Although present-day screens are of such construction that they are rather susceptible to damage, experience indicates that under normal photofluorographic conditions screens are seldom impaired accidentally even in the absence of protective glass. Furthermore, screens are now under development which are similar in design to intensifying screens in that they are covered by a thin transparent acetate film and therefore require no other protection.

From the foregoing it is clear that the benefits accruing from the use of protective glass are either non-existent or may be obtained equally well by other means. In view of the disadvantages of the glass it is [illegible] wise to dispense with it and in [illegible] advantage of the increased clarity of reproduction and contrast that will consequently occur.

REFERENCES

1. Morgan, R. H. [illegible] the diagnostic [illegible] images. Part [illegible] [illegible] Am. J. [illegible] & Rad. Therapy, [illegible] 125 [illegible]
2. Morgan, R. H. [illegible] images. Part II. [illegible] Am. J. [illegible] Rad. Therapy, [illegible]
3. Low [illegible] [illegible]

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EDITORIALS

THE TREATMENT OF LATE IRRADIATION ULCERS BY RADON IMPREGNATED VASELINE OINTMENT

IN NEARLY all radiotherapeutic departments a certain number of late irradiation injuries are observed which, from the point of view of management and treatment, often present a most difficult problem. They may be grouped into several categories. In some, an indolent ulcer develops within a heavily irradiated, although not overdosed area, many years after treatment was given with the customary technique for a common, as a rule malignant, neoplasm. In others, the ulceration is the result of a breaking down of an atrophic telangiectatic skin induced by an excessive irradiation of a harmless dermatologic condition. In still others, the injury is the end product of small repeated exposures over a long period of time during the course of professional work. Finally, with the advent of increasing use of the roentgen rays and radium in industry, not a few injuries are observed in technical workers who either through lack of sufficient protection or because of their own carelessness, are subjected to relatively large amounts of radiation.

There are many remedies recommended for the treatment of such late irradiation injuries. Their various indications and respective therapeutic values are well known and need not be expounded here. The fact remains that in the presence of a necrosing ulcer situated in a bed of over-irradiated skin or mucosa, many months or years are necessary before anything resembling a healing is accomplished. Often, radical surgical extirpation of the entire affected area constitutes the only method of approach left available.

In 1928 Uhlmann[1] began to use radon, absorbed in vaseline, for the treatment of persistent necrotic ulcers due to excessive irradiation. While the opinion seemed to prevail that an injurious effect produced by roentgen rays or radium could only be made worse by additional administration of the same agents, it was Uhlmann's idea that the alpha rays of the radon, if properly captivated, might lead to a beneficial action, mainly through influence on the blood vessels. According to most investigators, the cause of the late irradiation ulcers must be sought in the impaired blood supply incident to overexposure. Whether this damage is initiated by the selective destruction of the endothelial cells of the capillaries or results secondarily from the destruction of the nerves of the capillary walls, the destruction of the capillary system has a far-reaching effect on the future fate of the area so involved. Once a breaking down of the poorly vascularized tissues has set in, the main purpose of any treatment must consist in the restoration, if possible, of the blood circulation. Ordinary methods, while at times successful in the individual case, cannot be expected to lead to such an effect in general. Uhlmann demonstrated by histologic sections that vaseline, if applied to the skin under proper dressing, penetrates into the deeper layers of the cutis. Since, according to Strassburger's experiments, vaseline absorbs nine times as much radon as a similar volume of air and thirty-six times as much as water at room temperature, it is possible with the aid of such a vehicle, to make the alpha rays reach the capillary system in a relatively high con-

[1] Uhlmann, E. Treatment of injuries produced by roentgen rays and radioactive substances. Am. J. Roentgenol. & Rad. Therapy, 1939, *41*, 8[illegible]–92; also, Significance and management of radiation injuries. *Radiology*, 194[illegible], 3[illegible], 445–45[illegible].

centration. Although the radon during its process of decay also emits beta and gamma rays, the latter produce an ionization density no more than one one-hundredth of that of the alpha rays. It is assumed that this heavy bombardment of the tissues by the alpha particles leads to increased local capillary blood supply followed by a complete re-epithelization of the ulcer.

Based on such theoretical considerations, Uhlmann made a preparation by charging white or yellow petrolatum with radon in a concentration of about 100 electrostatic units per gram of vaseline, 1 electrostatic unit being equal to 0.000364 millicurie-destroyed. This concentration is quite weak so that it would take twenty times as much to produce an erythema in one seance. Since the radon decays at the rate of 16.5 per cent of its strength every twenty-four hours it is necessary that the ointment be prepared fresh before use, or if applied at a later date, that the proper dosage calculations be made to bring the intensity value up to that intended on the day of use. Exponential decay curves similar to those used with ordinary radon seed therapy will serve a good purpose in this connection.

The mode of application, as advocated by Uhlmann, is very simple. The ointment is spread with a spatula over the ulcer and immediately covered with a piece of rubber dam or oilcloth to prevent evaporation of the radon. The covering is fastened to the skin with overlapping adhesive strips. The duration of the application is, on an average, eight hours, after which the dressing is removed by the patient. The treatment is repeated two to ten times at weekly intervals, although in a few of the more severe cases as many as twenty treatments are required. The ulcer and surrounding skin are covered with a 10 per cent boric-beryllium ointment in the interval between the radon applications. In a series of 70 cases so treated very encouraging results were obtained.

Later, Kohn-Richards[2] introduced a semiautomatic pump for the preparation of the radon ointment, and made other innovations designed to increase the absorption of radon in vaseline or other media.

In a further study of the subject, Uhlmann and Grossman,[3] reviewing all the cases treated, found that the radon ointment proved so satisfactory in promoting granulation and epithelization in irradiation ulcers that when no healing occurred they were able to postulate and ultimately confirm that a malignant degeneration had taken place. The concentration of the radon ointment, as already stated, is too low to have any effect on a malignant neoplasm. Therefore, such a lesion, in contradistinction to the simple necrotic ulcer, continued to remain clinically active, despite the application of the radon ointment. So uniform was this observation, that Uhlmann and Grossman thought they could use it as a therapeutic test in differentiating between late irradiation necrosis and recurrent cancer.

Recently Cooper and Robertson[4] have published their favorable experience with the radon impregnated vaseline ointment at the Brisbane General Hospital. They have used the method since early in 1943 and obtained good results in all cases except those due to gross over-irradiation.

Cooper and Robertson prepare their ointment by breaking up ordinary radon seeds, used for routine radon moulds, in a jar of hot vaseline. After the jar has stood for twenty-four hours mixing is performed by melting and shaking, until a uniformity of distribution is obtained as evidenced by even fluorescence in the dark. The strength of the ointment is determined by measuring the gamma-ray emission of the whole jar before use.

The mode of application is along the same lines as that employed by Uhlmann.

[2] Kohn-Richards, H. Semi-authomatic vacuum double chamber for absorption of radon in fluid media. Am. J. Roentgenol. & Rad Therapy, 1942, *47*, 636–639.

[3] Uhlmann, E., and Grossman, A. Use of radon ointment as a means of differentiation between radiohecrosis and recurrent carcinoma. Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 620–623.

[4] Cooper, A.G.S., and Robertson, D.F. Treatment of post-irradiational ulcers by radon ointment. *Med. J. Australia*, 1945, *1*, 297–300.

The thickness of the ointment layer is immaterial since the alpha particles have a range which in the vaseline amounts to only a fraction of a millimeter, but a layer which is at least two to three millimeters thick guards better against loss of the radon. The concentration of the ointment varies from 0.024 to 0.060 millicurie per gram of vaseline. To enhance the tissue absorption of the ointment, the addition of 10 per cent lanolin is very effective. It is also advisable, especially in the painful cases, to interchange during the interim periods the dressings of unguentum acidi borici (10 per cent) with dressings of unguentum olei morrhuae with vaseline.

Cooper and Robertson have tried applications of from five to twenty-four hours at weekly and bi-weekly intervals but, like Uhlmann, gained the impression that an application of eight hours repeated once a week constituted the most desirable procedure. In the case of small ulcers the function of the ointment is to initiate healing, hence a very few applications are sufficient. In the larger ulcers weekly applications over a longer period of time may be necessary. If an ulcer is not considerably improved or reduced in size after four weeks, the presence of a malignant lesion is suspected.

The experience of Cooper and Robertson extends to a series of 69 cases. Of these, 20 proved to be recurrences of the original malignant lesion, 41 have been completely healed with a healthy epithelium and the remaining 8 have been improved to the extent that they can no longer be suspected of being malignant. Thus, in the entire series there is *not* one single case of an uncomplicated irradiation ulcer which has failed to respond to the treatment.

Stimulated by such splendid results, Cooper and Robertson also treated 15 recalcitrant varicose ulcers observed in 7 patients and 3 chronic ulcers occurring in scars following burns and surgery. Of the varicose ulcers, 9 healed promptly, 5 improved and only 1 failed to respond. The 3 ulcers of scars following burns and surgery healed completely without the addition of any other type of treatment.

Obviously, it is too early to assess the permanency of these results. For the present, it appears that ulcers which have healed continue to remain healed. It is the opinion of Uhlmann, and of Cooper and Robertson that the use of radon impregnated vaseline ointment constitutes a therapeutic method full of promise, not only in persistent late irradiation ulcers but also in certain other recalcitrant ulcers of various etiology.

T. Leucutia

Courtesy General Electric X-Ray Corp.

GLENN W. FILES
1897-1945

Glenn W. Files, director of the Technical Service Department of General Electric X-Ray Corporation since 1934, and an employee of the company for twenty-six years, died at the Alexian Brothers Hospital, Chicago, on September 11, 1945, at the age of forty-eight, following a heart attack. He resided at 2117-78th Ave., Elmwood Park, Illinois.

Born January 17, 1897, in Winfield, Kansas, Files began roentgen-ray work as a technician for a physician in that com-

munity, later meeting and working there with Dr. E. C. Jerman. In World War I, he was a sergeant in the Army, serving in France as an x-ray instructor and technician.

Files joined Victor X-Ray Corporation, predecessor of General Electric X-Ray Corporation, August 26, 1919, as an instructor under Dr. Jerman, director of the Education Department, and he became director following Dr. Jerman's retirement.

Widely acclaimed by the medical profession for his contributions to the development of roentgenologic technique and instruction methods, Files was the editor of the well known book, "Modern Radiographic Technic," published in 1943, of which 15,000 copies have been distributed. Files was editor-in-chief of "X-Ray Studies III," published in 1935, and he assisted in the publication of "Modern X-Ray Technic" in 1928, and "X-Ray Studies and Advanced Radiographic Technic" in 1931, edited by Dr. Jerman.

In addition, articles by Files appeared in the *X-Ray Technician* and the American Journal of Roentgenology and Radium Therapy, and for a time he contributed a column on x-ray technic to *Victor News.*

He was a member of the General Electric X-Ray Quarter Century Club; a member of the American Society of X-Ray Technicians, which he helped found; a member of the General Electric X-Ray Post of the American Legion; and he belonged to the Lakeview Lodge of A.F. and A.M.

He is survived by his wife, Alison, and by a brother Lennis of San Francisco.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. H. Dabney Kerr, University Hospital, Iowa City, Iowa. Annual meeting: 1945, canceled.

American College of Radiology
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago.

Section on Radiology, American Medical Association
Secretary, Dr. U. V. Portmann, Cleveland Clinic, Cleveland, Ohio. Annual meeting: 1945, canceled.

Arkansas Radiological Society
Secretary, Dr. J. S. Wilson, Mack Wilson Hospital, Monticello, Ark. Meets every three months and also at time and place of State Medical Association.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: 1945, to be announced.

Radiological Section, Baltimore Medical Society
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

Section on Radiology, California Medical Association
Secretary, Dr. Gordon G. King, 3700 California St., San Francisco 18, Calif.

Radiological Section, Connecticut Medical Society
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets bi-monthly on second Thursday, at place selected by Secretary. Annual meeting in May.

Section on Radiology, Illinois State Medical Society
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

Radiological Section, Los Angeles County Medical Association
Secretary, Dr. Roy W. Johnson, 1407 S. Hope St., Los Angeles, Calif. Meets on second Wednesday of each month at the County Society Building.

Radiological Section, Southern Medical Association
Secretary, Dr. Roy G. Giles, Temple, Texas.

Brooklyn Roentgen Ray Society
Secretary, Dr. Leo Harrington, 880 Ocean Ave., Brooklyn, N.Y. Meets monthly on fourth Tuesday, October to April.

Buffalo Radiological Society
Secretary, Dr. Joseph S. Gian-Francheschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months.

Chicago Roentgen Society
Secretary, Dr. F. H. Squire, 1754 W. Congress St., Chicago 12, Ill. Meets second Thursday of each month October to April inclusive at the Palmer House.

Cincinnati Radiological Society
Secretary, Dr. Samuel Brown, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

Cleveland Radiological Society
Secretary, Dr. D. D. Brannan, 11311 Shaker Blvd., Cleveland 4, Ohio. Meets at 6:30 P.M. at Allerton Hotel on fourth Monday each month, October to April, inclusive.

Dallas-Fort Worth Roentgen Study Club
Secretary, Dr. X. R. Hyde, Medical Arts Bldg., Fort Worth, Texas. Meetings held in Dallas on odd months and in Fort Worth on even months, on third Monday, at 7:30 P.M.

Denver Radiological Club
Secretary, Dr. A. Page Jackson, Jr., 1612 Tremont Place, Denver, Colo. Meets third Friday of each month at Denver Athletic Club.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

Florida Radiological Society
Acting Secretary, Dr. Walter A. Weed, 204 Exchange Bldg., Orlando, Fla. Meetings in May and November.

Georgia Radiological Society
Secretary, Dr. James J. Clark, 478 Peachtree St., Atlanta, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

Radiological Society of Kansas City
Secretary, Dr. Arthur B. Smith, 800 Argyle Bldg., Kansas City, Mo. Meets third Thursday of each month.

Illinois Radiological Society
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meets three times a year.

Indiana Roentgen Society
Secretary, Dr. H. C. Ochsner, Methodist Hospital, Indianapolis. Meets annually second Sunday in May.

Iowa X-Ray Club
Secretary, Dr. Arthur W. Erskine, 326 Higley Bldg., Cedar Rapids, Iowa. Luncheon and business meeting during annual session of Iowa State Medical Society. Special meetings by announcement.

Kentucky Radiological Society
Secretary, Dr. W. C. Martin, 321 W. Broadway, Louisville. Meets annually in Louisville on first Saturday in Apr.

Long Island Radiological Society
Secretary, Dr. Marcus Wiener, 1430-48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:30 P.M.

Louisiana Radiological Society
Secretary, Dr. J. R. Anderson, 1130 Louisiana Ave., Shreveport. Meets annually during Louisiana State Medical Society Meeting.

Michigan Association of Roentgenologists
Secretary, Dr. E. M. Shebesta, 1429 David Whitney Bldg., Detroit. Three meetings a year, Fall, Winter, Spring.

Milwaukee Roentgen Ray Society
Secretary, Dr. C. A. H. Fortier, 231 W. Wisconsin Ave., Milwaukee, Wis. Meets monthly on second Monday at University Club.

Minnesota Radiological Society
Secretary, Dr. Annette T. Stenstrom, 1218 Medical Arts Bldg., Minneapolis, Minn. One meeting a year at time of Minnesota State Medical Association.

Nebraska Radiological Society
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month, at 6 P.M. at either Omaha or Lincoln.

New England Roentgen Ray Society
Secretary, Dr. George Levene, Massachusetts Memorial Hospitals, Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

New Hampshire Roentgen Ray Society
Secretary, Dr. Richard C. Batt, Berlin, N. H. Four meetings a year.

Radiological Society of New Jersey
Secretary, Dr. H. R. Brindle, 501 Grand Ave., Asbury Pk. Meets annually at time and place of State Medical Society. Mid-year meetings at place chosen by president.

New York Roentgen Society
Secretary, Dr. Ramsay Spillman, 115 East 61st St., New York City. Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

North Carolina Roentgen Ray Society
Secretary, Dr. Major Fleming, Rocky Mount, N. C. An-

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

nual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

North Dakota Radiological Society
Secretary, Dr. L. A. Nash, St. John's Hospital, Fargo. Meetings held by announcement.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

Ohio Radiological Society
Secretary, Dr. Henry Snow, 1061 Reibold Bldg., Dayton, Ohio. Meets during annual meeting of Ohio State Medical Association.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport.

Philadelphia Roentgen Ray Society
Secretary, Dr. C. L. Stewart, Jefferson Hospital, Meetings first Thursday of each month, October to May, at at 8:00 p.m., in Thomson Hall, College of Physicians, 21 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. L. M. J. Freedman, 4800 Friendship Ave. Meets 6:30 p.m. at The Ruskin on second Wednesday, each month, October to May inclusive.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Murray P. George, Strong Memorial Hospital. Meets monthly on third Monday from October to May, inclusive, 8 p.m. at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary Dr. A.M. Popma, 220 N. First St., Boise, Idaho.

St. Louis Society of Radiologists
Secretary, Dr. Edwin C. Ernst, Beaumont Medical Building, St. Louis, Mo. Meets fourth Wednesday of each month, except June, July, August, and September, at a place designated by the president.

San Diego Roentgen Society
Secretary, Dr. Henry L. Jaffe, Naval Hospital, Balboa Park, San Diego, Calif. Meets monthly on first Wednesday at dinner.

San Francisco Radiological Society
Secretary, Dr. Carlton L. Ould, University of California Hospital, San Francisco 22. Meets monthly on the third Thursday at 7:45 p.m., first six months of the year at Lane Hall, Stanford University Hospital, and second six months at Toland Hall, University of California Hospital.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 p.m., September to May inclusive.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, 707 Walnut St., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. Asa E. Seeds, Baylor Hospital, Dallas, Texas. Next annual meeting, Temple, Texas, Jan. 17, 1945.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 p.m. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 p.m., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. E. L. Flanagan, 116 E. Franklin St., Richmond, Va. Meets annually in October.

Washington State Radiological Society
Secretary. Dr. Thomas Carlile, 1115 Terry St., Seattle. Meets fourth Monday each month, October through May, College Club, Seattle.

X-Ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly, third Thursday evening.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Medical Members' meeting held monthly on third Friday at 2:30 p.m. and Ordinary Meeting at same time on following Saturday, October to May, 32 Welbeck St., London, W.1.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month at 4:45 p.m. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. J. W. McKay, 1620 Cedar Ave., Montreal, P. Q.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

South America

Sociedad Argentina de Radiologia
Secretary, Dr. Guido Gotta, Buenos Aires, Argentina. Meetings are held monthly.

Sociedad Peruana de Radiologia
Secretary, Dr. Victor Giannoni, Apartado, 2306, Lima, Peru. Meetings held monthly except during January, February and March, at the Asociación Médica Peruana "Daniel A. Carrión, Villalta 218, Lima.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse Biel. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad: USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 p.m.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

SECOND INTER-AMERICAN CONGRESS OF RADIOLOGY

In the April, 1945, issue of the Journal a preliminary announcement was made of the Second Inter-American Congress of Radiology which was planned at that time to be held in Havana, Cuba, January 19–24 1946. Since that announcement was made it has been decided, for a number of reasons that it was best to postpone the Congress and the dates now chosen are November 17–22, 1946. A more extended notice appears in advertising page xvii of the September issue of the Journal. The place of the meeting is still to be Havana and the President of the Congress is Dr. Pedro L. Fariñas. Inquiries for further information should be addressed to the Secretary-General, Dr. R. Hernandez Beguerie, Calle 23, No. 411, Vedado, Havana, Cuba.

REPRINTS WANTED BY FRENCH RADIOLOGISTS

In a communication recently received from Dr. Robert Coliez, Vice-President of the Association of French Radiologists, the radiologists of France send their greetings to their colleagues in the United States after the long years of war. Having received practically no scientific papers on radiology from the United States during these years, they are anxious that American radiologists send reprints of articles on the following subjects which have appeared since 1939: (1) diagnostic roentgenology; (2) roentgen therapy; (3) radium therapy and neutron therapy; (4) electrology; (5) cancerology; also progress in apparatus and techniques, clinical results, and so forth, between 1939 and 1945. Reprints should be sent to Docteur Robert Coliez, 25, Rue Franklin, Paris, XVIème, France.

CANCER TEACHING DAYS

A Cancer Teaching Day was held in Middletown, New York, on September 18, 1945, under the auspices of various county and state medical societies. The speakers on the program and their subjects were as follows: "Cancer of the Skin and Allied Tumors" by Dr. Earl D. Osborne, Buffalo, New York; "Cancer of the Uterus and Vagina" by Dr. Arthur J. Wallingford, Albany, New York; "Diagnosis and Curability of Intraoral Cancer" by Dr. Hayes Martin, New York; "Cancer of the Breast" by Dr. Cushman D. Haagensen, New York; "Cancer of the Colon and Rectum" by Dr. George E. Binkley, New York.

On October 9 an evening meeting was held in Rochester, New York, at which the following two papers were given: "Carcinoma of the Colon" by Dr. John H. Garlock, New York; "Progress in Cancer Research" by Dr. John J. Morton, Jr., Rochester, New York.

BOOK REVIEWS

Books sent for review are acknowledged under "Books Received." [illegible] for the courtesy of the sender. Selections will be made for review [illegible]

Radiation and Climatic Therapy of Chronic Pulmonary Diseases: With Special Reference to Natural and Artificial Heliotherapy, X-ray Therapy, and Climatic Therapy of Chronic Pulmonary Diseases and All Forms of Tuberculosis. Edited by Edgar Mayer, M.D., F.A.C.P., F.A.C.C.P., Assistant Professor of Clinical Medicine, Cornell University Medical College, New York City; Attending Physician New York and Memorial Hospitals; Special Pulmonary Consultant, New York State Department of Labor, etc., with the collaboration of 22 other contributors. Cloth. Price, $5.00. Pp. [illegible], with numerous illustrations. Baltimore, Maryland: Williams & Wilkins Company, [illegible].

This book is a compilation of the use of natural and artificial light, of solar radiation, climatotherapy and roentgen therapy in a number of diseases. An editor and [illegible] collaborators express their ideas on the treatment of chronic diseases of the lungs, including tuberculosis, and of all extrapulmonary tuberculosis.

The book presents in brief [illegible] elementary form the physical [illegible] the physiological action and clinical effects of light from selected portions of the spectrum [illegible] the skin [illegible]

[illegible]

and Michigan Department of Health for general practitioners to assist them in diagnosing early cancer and in determining the type of treatment that should be employed. It is well arranged. Chapters have been contributed by competent Michigan physicians, surgeons, radiologists, and pathologists. Clinical and laboratory diagnoses, pathology, and courses of cancers of most organs are described briefly but adequately without indulging in technical terminology. Surgical and radiological treatments are discussed but not in detail, because, as stated in the preface, "cancer therapy is a highly specialized matter requiring extensive experience—." In addition there are chapters dealing with subjects of general interest about cancer. One on "Care of the Advanced Cancer Patient" and another on "Neurosurgical Relief of Pain" are also appropriate. Similar manuals have been published in several states and undoubtedly have been useful, especially in making physicians "cancer conscious."

U. V. Portmann

Tuberculosis of the Ear Nose and Throat: Including the Larynx, the Trachea, and the Bronchi. By Mervin C. Myerson, M.D., New York City. Cloth. Price, $5.50. Pp. 291, with 88 illustrations. Springfield, Illinois: Charles C Thomas, 1944.

Myerson has presented impressions which he has gained from the study of one thousand cases of tuberculous laryngitis which, in his experience, occurs in 10 per cent of all cases of tuberculosis. He has described the pathology, symptomatology, diagnosis and treatment of this affection. At times rather didactic and lecture like, his story is concise. Differential diagnosis seems to present difficulties only seldom if one always keeps syphilis in mind. Treatment is unsatisfactory because the issue depends more upon the course of the almost always underlying pulmonary tuberculosis and the ability of the tissues to heal than upon the therapeutic maneuvers tried, chief of which are electric cautery and vocal rests.

The chapter on nontuberculous lesions of the larynx presents the chief elements of the differential diagnosis. Tuberculosis of the middle ear appears to exist more frequently than is commonly supposed, and is usually without symptoms until aural discharge or impairment of hearing develops.

One is greatly surprised to read that tuberculosis of the tonsils occurs in 25 per cent of cases of pulmonary tuberculosis in this author's series. This must mean, of course, that his were by the very nature of their referral, selective, for the physician treating the average case of tuberculosis is always surprised when he sees this, to him, very occasional complication. The author has wisely advised complete examination of the patient before tonsillectomy.

In his discussion of tuberculosis of the bronchi many a phthisiologist will take exception to the statement that recovery of tubercle bacilli from the orifice of a bronchus identifies the lobe containing the lesion, for many believe that any portion of the bronchial tree may contain tubercle bacilli at times, at least in the case with cavity. "Since atelectasis is the mechanism by which a local anoxemia is produced and the tubercle bacilli destroyed, the ulcero-granuloma which occludes a bronchus must be considered Nature's instrument for healing a cavity." Are tubercle bacilli so easily disposed of by nature? In several instances where the author has stepped out of his specialty to discuss the dynamics of tuberculosis and collapse therapy he has appeared to get into deep water. In general, however, his discussion of bronchial tuberculosis and especially of contraindications to bronchoscopic treatment are sound, and he makes an unusually interesting story of the reopening of a tuberculous bronchus as spontaneous retrogression occurs.

Altogether the physician not a specialist in conditions of the nose and throat may obtain helpful information by reference to this book.

H. S. Willis

Control of Pain in Childbirth: Anesthesia; Analgesia; Amnesia. By Clifford B. Lull, M.D., F.A.C.S., Clinical Professor of Obstetrics, Jefferson Medical College; Assistant Director, Philadelphia Lying-In Unit, Pennsylvania Hospital, and Robert A. Hingson, M.D., Surgeon, U. S. Public Health Service; Director, Post-graduate Medical Course, Philadelphia Lying-In Unit, Pennsylvania Hospital. With an Introduction by Norris W. Vaux, M.D., Obstetrician-in-Chief, Philadelphia Lying-In Unit, Pennsylvania Hospital. Cloth. Price, $7.50. Pp. 356, with 100 illustrations in black and white and 32 subjects in color, Philadelphia: J. B. Lippincott Company, 1944.

A comprehensive survey of obstetric anal-

gesia and anesthesia is presented in this volume. The value of the book is enhanced by the co-authorship involving thoroughly competent men in the two sciences concerned.

The book opens with a concise but adequate consideration of the anatomy and physiology of the pelvis pertinent to obstetric pain relief. This is followed by a classification and discussion of the various agents used to provide analgesia, anesthesia, and amnesia, describing their important characteristics. The mode of application of these agents is dealt with in some detail. Special attention is also given to the use and effects of the several agents in relation to the third stage of labor, cesarean section, and the puerperium. The final section of the book deals with the selection and use of the methods of pain relief in the presence of maternal complications, and also with their effects on resuscitation of the infant.

The book makes liberal use of illustrations and charts. Especially informative are the figures which show graphically the effects of the various agents for pain relief upon the vital organs of both mother and infant.

It is a compliment to the authors that although they have done more than anyone else to develop and refine caudal analgesia, they do not present it as a panacea. This procedure is given its rightful place among the others, each with its own attributes and disadvantages.

This work fills a long felt need and should find ready and widespread acceptance.

R. S. Haas

BOOKS RECEIVED

Radiologic Examination of the Small Intestine. By Ross Golden, M.D., Professor of Radiology, College of Physicians and Surgeons, Columbia University; Director of the Radiological Service, Presbyterian Hospital, New York. Cloth. Price, $[illegible]. Pp. 23[illegible], with [illegible] illustrations. Philadelphia: J. B. Lippincott Company, 1945.

X-Ray Examination of the Stomach. A Description of the Roentgenologic Anatomy, Physiology, and Pathology of the Esophagus, Stomach, and Duodenum. By Frederic [illegible] Templeton, M.D., Head of the Department of Roentgenology, [illegible]. Cloth. Price, $[illegible]. Pp. [illegible], with [illegible] illustrations. Chicago: University of Chicago Press, [illegible].

The Gastrointestinal Tract. A Handbook of Roentgen Diagnosis. By [illegible] Hodges, B.S., M.D., Professor of Roentgenology, University of Michigan Medical School, Ann Arbor, Michigan. Cloth. Price, $5.00. Pp. [illegible], with numerous illustrations. Chicago: Year Book Publishers, Inc., [illegible].

Clinical Roentgenology of the Digestive Tract. By Maurice Feldman, M.D., Assistant Professor of Gastroenterology, University of Maryland; Assistant in Gastroenterology, Mercy Hospital; [illegible], Roentgenologist, Sinai Hospital, [illegible]. Cloth. Price, $[illegible]. Pp. [illegible], with [illegible] illustrations. Baltimore: Williams & Wilkins Company, 1945.

Mass Radiography of the Chest. By Herman E. Hilleboe, M.D., Medical Director, Chief, Tuberculosis Control Division, United States Public Health Service; [illegible] Lecturer on Tuberculosis, [illegible], George Washington University School of Medicine, Washington, D. C., and Russell H. Morgan, M.D., Surgeon (R), Medical Officer in Charge, Radiology Section, Tuberculosis Control Division, United States Public Health Service; Assistant Professor of Roentgenology, Absent on Leave, University of Chicago. Cloth. Price, $[illegible]. Pp. [illegible], with [illegible] illustrations. Chicago: Year Book Publishers, Inc., 1945.

The Urinary Tract. A Handbook of Roentgen Diagnosis. By [illegible], M.D., Professor of Radiology, State University of Iowa College of Medicine, and [illegible], M.D., Associate Professor of Radiology, State University of Iowa [illegible]. Cloth. Price, $[illegible]. Pp. [illegible], with [illegible] illustrations. Chicago: Year Book Publishers, Inc., 1944.

[illegible]

low, With the technical assistance of G. S. Innes, B.Sc., A.M.I.E.E., Physicist to the Mozelle Sassoon Department. With a Foreword by the Rt. Hon. The Lord Horder, G.C.V.O., M.D., F.R.C.P., Cloth. Price, 16s. Pp. 142, with 95 illustrations. London: H. K. Lewis & Co., Ltd., 1943.

X-Ray Isodose Curves. Compiled by the Staff of the Physics Department of the Royal Cancer Hospital (Free), London, S.W.3. 45 kv., 60 kv., 140 kv. (peak), 200 kv., 400 kv. (peak), isodose curves. Reprint of Percentage Depth Dose Tables supplied with each set of curves. Isodose curves contained in stout cardboard portfolios. Complete set at £10.10s od. Royal Cancer Hospital (Free), Fulham Road, London, S.W.3, England.

The Pathogenesis of Tuberculosis. By Arnold R. Rich, M.D., Associate Professor of Pathology, Johns Hopkins University School of Medicine, Baltimore. Cloth. Price, $10.50. Pp. 1008, with 89 illustrations. Springfield, Illinois: Charles C Thomas, 1944.

The Fundamentals of Electrocardiographic Interpretation. Second edition. By J. Bailey Carter, M.D., F.A.C.P., Assistant (Rush) Professor, Department of Medicine, University of Illinois College of Medicine; Attending Staff, Cook County Hospital, Augustana Hospital, Chicago. With a Foreword by Horatio Burt Williams, M.D., Dalton Professor of Physiology, College of Physicians and Surgeons, Columbia University, New York. Cloth. Price, $6.00. Pp. 406, with 309 illustrations. Springfield, Illinois: Charles C Thomas, 1945.

Shoulder Lesions. By H. F. Moseley, M.A., D.M., M.Ch.(Oxon.), F.R.C.S. (Engl and C.) F.A.C.S., Montreal, Canada, Lecturer in Surgery, McGill University; Assistant Surgeon, Royal Victoria Hospital. Cloth. Price, $4.50. Pp. 184, with 70 illustrations. Springfield, Illinois: Charles C Thomas, 1945.

Neuro-ophthalmology. By Donald J. Lyle, B.S., M.D., F.A.C.S., Lecturer on Neuro-ophthalmology, Department of Anatomy, Medical College of the University of Cincinnati; Attending Ophthalmologist to the Good Samaritan Hospital, Christ Hospital, Jewish Hospital, St. Mary's Hospital and Children's Hospital. Cloth. Price, $10.50. Pp. 398, with 529 illustrations. Springfield, Illinois: Charles C Thomas, 1945.

Control of Pain in Childbirth: Anesthesia; Analgesia; Amnesia. By Clifford B. Lull, M.D., F.A.C.S., Clinical Professor of Obstetrics, Jefferson Medical College; Assistant Director, Philadelphia Lying-In Unit, Pennsylvania Hospital, and Robert A. Hingson M.D., Surgeon, U. S. Public Health Service; Director, Post-graduate Medical Course, Philadelphia Lying-In Unit, Pennsylvania. With an Introduction by Norris W. Vaux, M.D., Obstetrician-in-Chief, Philadelphia Lying-In Unit, Pennsylvania Hospital. Cloth. Price, $7.50. Pp. 356, with 100 illustrations in black and white and 32 subjects in color. Philadelphia: J. B. Lippincott Company, 1944.

Plaster of Paris Technic. By Edwin O. Geckeler, M.D., Associate Professor of Orthopaedic Surgery, and Chief of the Fracture Service, Hahnemann Medical College and Hospital, Philadelphia. Fellow of the American College of Surgeons, Fellow of the American Academy of Orthopaedic Surgeons, etc. Cloth. Price, $3.00. Pp. 220, with 208 illustrations. Baltimore: Williams Wilkins Company, 1944.

A Bibliography of Aviation Medicine: Supplement. By Phebe Margaret Hoff, Ebbe Curtis Hoff and John Farquhar Fulton. Cloth. Price, $2.50. Pp. 109. Published by the Committee on Aviation Medicine, Division of Medical Sciences, National Research Council, Acting for the Committee on Medical Research. Office of Scientific Research and Development, Washington, D. C. Distributed by Charles C Thomas, Springfield, Illinois.

Anatomy: As a Basis for Medical and Dental Practice. By Donald Mainland, M.B., Ch.B., D.Sc. F.R.S.E., F.R.S.C., Professor of Anatomy, Dalhousie University, Halifax, N.S., Canada. Cloth. Price, $7.50. Pp. 863, with 61 illustrations. New York: Paul B. Hoeber, Inc., 1945.

Poet Physicians: An Anthology of Medical Poetry Written by Physicians. Compiled by Mary Lou McDonough. Cloth. Price, $5.00. Pp. 212. Springfield, Illinois: Charles C Thomas, 1945.

Abridged Scientific Publications. From the Kodak Research Laboratories. Volume xxv, 1943. Paper. Pp. 443, with numerous illustrations. Rochester, New York: Eastman Kodak Company, 1944.

DEPARTMENT OF TECHNIQUE

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A METHOD FOR IMPROVING ROENTGENOGRAMS OF THE CHEST

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THE appearance within recent years of the so-called "automatic control panel" for high-powered roentgen-ray generators makes practical a change for the better in the usual method of adjusting roentgen-ray exposure of the chest to size of the patient. Heretofore it has been the custom to change the voltage according to the thickness and type of chest but technically this is not the best approach because the contrast of the resultant roentgenograms varies even if the maximum blackening in the lung fields is held constant. There are three principal factors responsible for this change in contrast: (1) at the higher voltage used on a larger patient, the rays generated are of shorter wavelength; (2) there is increased scattering because of the shorter wavelength radiation used; and (3) there is increased scattering from the greater mass of tissue penetrated. Shorter wavelength radiation and increased scattering both produce a roentgenogram of lessened contrast. Conversely, with a patient thinner than the standard, an exposure with lowered kilovoltage produces a roentgenogram of increased contrast. Differences in contrast are only too apparent in any group of routine roentgenograms of the chest.

It would be an advantage if all roentgenograms of the chest, regardless of the patient's size and build, could be of the same technical quality: the same contrast and the same maximum blackening within the lung fields. To realize this the voltage used for a heavier patient should not be increased but rather should be decreased in order that the longer wavelength radiation so produced might balance the flattening of the roentgenogram caused by greater scattering mass. The increased exposure required to compensate for the greater absorption plus the loss from lowered voltage must be made up in some way which will not change the quality of the finished roentgencgram. Assuming that the basic voltage is, as it should be, high enough to adequately penetrate the heaviest subjects, variable patient absorption may best be compensated for by changing the milliampere-seconds used. Change of distance is unacceptable for the resultant change in geometric unsharpness is undesirable. Change in time of exposure can be considered where an impulse timer is available permitting changes by steps of 2 impulses (an exposure with an odd number of impulses should be avoided) although the variation in movement unsharpness is not to be desired. In fact, where an automatic control is not installed, a standard technique based upon 6 impulses may be adopted and changed to 4, 8, 10 or 12 impulses as the case at hand may require with results from the standpoint of the quality of the roenrgenogram that justify the method. For it may be better to have good contrast on all types of cases at the expense

of possible movement unsharpness on a few of the heavier ones (at 1/10 second not more than one in five roentgenograms is apt to be taken during an instant when lung movement at any place is enough to cause noticeable unsharpness) than to accept poorer contrast quality in a considerable number of cases. The best way is by a change in milliamperage but heretofore it has not been possible to do this conveniently and rapidly and still keep control of the voltage calibration; this has been especially true with the rotating anode tubes used with high-powered generators for they do not operate above saturation potential. The automatic controls now make it possible to vary milliamperage freely.

Automatic control refers to the modern control board for use with a 500 ma. transformer and rotating anode tube, which includes these three features: (1) a "technique selector" by means of which one can set a single control to a given "station" and secure a stated milliamperage; (2) an arrangement whereby roentgen tube space-charge is compensated so that milliamperage is held constant as kilovoltage is changed, and (3) an arrangement whereby the kilovoltage indicator reads the true calibration at whatever milliampere station may be selected. The technique selector on such units makes possible rapid and accurate setting of milliamperage to, usually, any multiple of 100 ma. up to and including 500 ma.; it is this ease, coupled with the accurate knowledge of kilovoltage calibration at each station, that permits the use of milliamperage as well as kilovoltage as a variable for routine roentgenography of the chest. Steps of 100 ma. are too coarse to allow use of milliamperage as the only variable so with present machines the finer control of 1 kv. autotransformer steps must still be used, but with the combination a positive move in the direction of holding contrast uniform on the roentgenograms of all patients can be made.

In practice, a technique standard for the average range of cases can be worked out on the basis of 300 ma. over a scope of about 6 kv. For example, an 18 cm. chest might call for an exposure of 63 kv. and the voltage would be increased to 69 kv. for 21 cm. chests. But in the next bracket where voltages up to 74 kv. would usually be called for, the selector is set at 400 ma. and 5 kv. less voltage is given, while in the higher range which might ordinarily require 75 kv. or more the selector is set at 500 ma. and 9 kv. subtracted from the scale. Conversely, for thin patients, instead of going below 63 kv. the selector is set to 200 ma. and 6 kv. added to what would have been given. Thus, except for unusual conditions, the films are all exposed within the range of 63 to 69 kv.; not much change in contrast could be expected from the change in radiation over that small a range, so such differences in roentgenograms as do occur are probably caused by the scattering factors of the flesh. This method has proved both practical and beneficial in routine use; both milliamperes and kilovolts can be rapidly set at the desired combination, and the resultant roentgenograms, especially of the heavier cases, are decidedly improved. Identical contrast on roentgenograms of every type of case cannot be expected, for only a partial step in the necessary direction can be taken and it is to be anticipated that after major differences in contrast are compensated for the control of smaller changes will be more difficult as the influence of obscure factors becomes effective, but because of the ease with which a considerable improvement can be made the method is worth trying.

A 300 ma. basic technique is adequate. In addition to the kv-ma. combination outlined above, other factors as used at Firland Sanatorium include: 1/20 second, 6 foot distance, detail type screens in bakelite cassettes, and development for 2½ minutes at 70° in speed developer.

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ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

NECK AND CHEST

Edwards, H. R. Tuberculosis in industry. *Am. J. M. Sc.*, April, 1943, *205*, 571–581.

The author of this study is Director of the Bureau of Tuberculosis, Department of Health, New York City. This paper is a statistical evaluation of the findings in the roentgenographic examination of 15,644 union workers in various industries in New York City. The findings in these studies confirmed previous observations that as a group the employed population invariably reveals less significant pulmonary tuberculosis than those employed on relief. It is also obvious that the prevalence of tuberculosis varies considerably on the basis of occupation but that so far as evidence is available here there is no reason to believe that the occupation studied can be considered as direct causative agent in tuberculosis.

There was found to be a prevalence rate of 0.61 per cent with evidence of clinically significant pulmonary tuberculosis. The prevalence of chronic pulmonary tuberculosis of apparent arrest was 2.9 per cent. The prevalence of healed primary lesions for the entire group was 12.43 per cent.

Surveys of this type have been shown to be valuable in revealing the prevalence of chronic pulmonary tuberculosis and should be the basis for a definite program in medical care of the industrial employee. Such a service should provide pre-employment as well as periodic re-examination.

The handling of the pulmonary phase of such services requires competent clinicians trained in chest pathology; otherwise overemphasis may be placed on lesions of no importance as well as the reverse. If such work is properly carried out, there is no reason to believe that the worker will be unjustly discriminated against because he presents a pulmonary lesion.

It is felt that the establishment of a Tuberculosis Control Program in all industries is amply justified. Such a program is greater than can be handled by the local department of health and is a responsibility that should be shared jointly by management and organized labor.—*J. J. McCort.*

Ehrlich, David E., Schiller, Israel A., and Edwards, Herbert R. Army x-ray examination for tuberculosis. *Am. Rev. Tuberc.*, Feb., 1943, *47*, 113–120.

This study is based upon 114,130 roentgenographic examinations of selective service registrants and National Guardsmen such as examined at the Army physical examination centers of the Southern New York District. In particular, the authors are interested in the comparative use of 14×17 inch paper films versus the 4×5 inch photoroentgenograms.

They found that reclassifications occurred about half as frequently when restudying cases which had first been studied by the 14×17 inch paper films, versus the 4×5 inch films. No mention is made of stereoscopic studies with either of these methods. The authors are very fair in their explanation of the difference in their trust of these two methods—stating that they were less familiar with the miniatures.

Taking into consideration the various bases for rejection because of findings in the chest, as stipulated in MR 1–9, the following conditions were identified: tuberculosis, primary and reinfection types, 352 cases; bronchiectasis, 57; pleural lesions, 21; spontaneous pneumothorax, 13; mediastinal lymphadenopathy, 12; cysts and tumors, 12; pneumonias, 11; fibrosis, 8; pneumonoconiosis, 4; undetermined lesions, 4; bronchial stenosis, 2; diaphragmatic hernia, 2 and congenital heart abnormalities, 2. Considering all of these 1.14 per cent were rejected; 1.01 per cent being identified as chronic pulmonary tuberculosis (0.38 per cent considered to be clinically significant).

It is estimated by the authors that the savings to the Federal Government, by these rejections, amounted to approximately thirteen million dollars.—*A. A. de Lorimier.*

Thomas, Morris C. Types of lung diseases encountered in an Army camp. *Am. Rev. Tuberc.*, July, 1943, *48*, 1–7.

The author has studied chest conditions such as those found at the Station Hospital, Fort Knox. Three groups of personnel were concerned: those of the Regular Army (physically capable of the rigors of field duty), the first selectees of 1941 (carefully selected as of physical and mental perfection), and the inductees (selected after the break of war, and brought in on such a large scale that inconspicuous defects could be passed—requiring the stress of training to uncover).

All of these groups were treated alike and the author has been interested in noting differences in their disease findings.

Spontaneous pneumothorax was encountered occasionally; traumatic pneumothorax, rarely. Bronchiectasis appeared to be more common than tuberculosis (possibly because it was more difficult to identify the former at the induction centers). There were many asthmatics (probably because history of asthma did not suffice for exemption; witness of definite attacks being necessary). Hemoptysis was not taken at face value; it occurred too frequently among malingerers and bronchoscopies were frequently performed—for it was "learned that a malingerer doesn't relish a second bronchoscopy." Three pulmonary malignancies were identified, even in this younger group (2 carcinomas and 1 sarcoma). Lung cysts and pneumoconiosis were oddities (apparently eliminated at induction centers). Three cases of rheumatic involvement of the lungs (accompanied by pericarditis and endocarditis) occurred. There was one epidemic of influenza, occurring in December, 1940 (with no pulmonary complications).

The pneumonias accounted for the largest group of major pulmonary infections, with 2 deaths in two years. The peak of such disturbance occurred in March and April. There appeared to be several distinct types.

Only a small group were pneumococcic. These followed the customary course, except that they were admitted for hospital care earlier than in the usual civilian practice; after sulfonamide therapy there appeared to be very little progress of the pathological process in the lungs.

In February, 1941, there seemed to be a second form of pneumonia—having prodromal symptoms for one to five days and the pneumonia itself developing as a complication of pharyngitis, or other disease. The symptoms of non-productive cough, substernal pain, pleural pain, fever of 100–103 F., and white blood counts averaging around 15,000 were all out of proportion to physical and roentgen findings (a patchy, lobular type of consolidation frequently confined to the right middle lobe; occasionally, the appearance of cavitation; clearing of one area and subsequent consolidation elsewhere). Pneumococci could not be found in these cases.

Later in the spring of 1941, a third form of pneumonia developed—the patients were quite ill; white blood counts averaged over 25,000; non-typable pneumococci were demonstrated in the sputum of about half the group, and there was expectoration of frank blood in many cases. Roentgenography revealed fairly extensive involvement—the appearance of incomplete lobar consolidation.

In the fall of 1941, a fourth type of pneumonia appeared—symptoms varied from none to severe; roentgenography revealed extensive involvement in some cases where there were few or no symptoms; sputum was frequently mucoid and blood tinged; sore throats, headaches, anorexia were frequent; cyanosis was absent or faintly perceptible; some had no fever though the majority showed a fever of 102–104° F.; respirations were normal while the pulse coincided with the fever curve; white blood counts were normal or there was a mild leukocytosis, not exceeding 15,000. Serial roentgenography revealed a tendency toward fleeting involvements with hilar shadows enlarged and otherwise slight mottling to extensive consolidations.

A fifth form of pneumonia was noted during 1942—sudden onset with extreme prostration; harassing cough uncontrolled by large doses of codeine; sputum blood-tinged to frank blood; severe retrosternal pain; cyanosis which was persistent and only partially relieved by oxygen; physical finding of râles through most of the lung fields, and a constant finding of white blood count below 8,000. The severity of this infection appeared to be proportionate to the degree of leukopenia. Convalescence was slow. There was no response to chemotherapy.—*A. A. de Lorimier.*

Rilance, Arnold B., and Gerstl, Bruno. Bronchiectasis secondary to pulmonary tuberculosis. *Am. Rev. Tuberc.*, July, 1943, 48, 8–24.

This report is concerned with 47 tuberculous patients in whom bronchiectasis was identified by way of bronchography or found at autopsy. In 35 of these, the diagnosis was based upon

lipiodol studies alone; in 12, the bronchial dilatations were demonstrated at autopsy. In 3 of the 35 patients, the bronchiectasis was considered to be independent of the tuberculous process; in the other 32 it was thought to be the direct result of the tuberculosis. In the former group, there was the typical foul sputum with clubbing of the fingers, long before any evidence of tuberculosis. Among the latter group, the sputum was not foul and clubbing of the fingers was not noted.

The incidence of bronchiectasis in tuberculosis has been variously reported; cited to be as often as 61 per cent of active cases. It may be due to bronchial stenosis, pulmonary fibrosis or to dilatation directly resulting from impairment and infection.

The findings of 7 cases are described in detail. The authors are of the opinion that the bronchiectasis is usually not directly due to the abnormality of bronchial functioning; that the few which are so related are featured by greater severity of symptoms of a bronchiectatic character. Suspicion of the presence of tuberculous bronchiectasis should be aroused when patients present the clinical symptoms of tuberculosis, in association with either persistently negative sputum or a roentgen picture which by itself would be interpreted as a healed tuberculous lesion.

In 1 of the cases, the pathological studies indicated development of saccular bronchiectasis by way of re-epithelialization of a tuberculous cavity.—*A. A. de Lorimier.*

Ellison, Richard T., and Gershon-Cohen, J. "Physiological" changes in breath sounds and tuberculosis. *Am. Rev. Tuberc.*, May, 1943, *47*, 449–459.

An effort has been made to correlate alterations in physical signs in the right apex with changes as shown roentgenographically and with tuberculin reactions. This study involved examination of 450 cases which were unselected but outpatients in a clinic (Philadelphia) for tuberculosis.

Tuberculous involvement in the hilar and tracheobronchial lymph nodes appeared to produce retraction of the apex, asymmetry of the musculature and subcutaneous tissues and alterations in breath sounds. The primary phase of tuberculosis appeared to be most frequently responsible for these lymphatic and secondary changes. The atrophy of musculature and subcutaneous tissues may be explainable on the basis of hypofunction, but the authors emphasize that hypoventilation may be the essential factor.—*A. A. de Lorimier.*

Leonidoff, Aleksei A. Tuberculosis in mentally ill patients. *Am. Rev. Tuberc.*, May, 1943, *47*, 460–468.

There is growing concern because of the prevalence of tuberculosis in hospitals for the mentally ill. At the Hudson River State Hospital at Poughkeepsie, New York, a careful search has been made of patients, in this regard, especially since 1936. Mantoux tests with PPD and also the Vollmer patch test were compared. The Mantoux showed the greater incidence of positive reaction, though the difference was not very great. There were shortcomings to either method, as far as cooperation of the patients was concerned. Roentgenoscopy was found to be unsatisfactory for several reasons: lack of familiarity with the procedure by many psychiatrists; the time required; the lack of cooperation of the patient, and the fact that this method fails to detect "a little over 5 per cent of pulmonary tuberculosis." Ordinary physical examinations were likewise unreliable—as were also details of history and present illness. Even the matter of weight loss could not be considered suggestive of tuberculosis, since so often this was due to psychic disturbance. Sedimentation rates were studied but they were considered to be relatively tardy in their indications. Pulse rate and temperature studies presented confusing data.

Finally, mass roentgenography was instituted and 752 of the 7,466 patients were isolated on the basis of suspicious evidence. Corroborative studies revealed an incidence of 8.8 per cent of significant tuberculosis. Similar studies were thereafter accomplished on employees—resulting in the identification of tuberculosis in 2.8 per cent.

As a result of these revelations, certain policies were established: to re-examine all employees every four months, or more frequently; to dissuade younger persons against work in a tuberculosis service; to enforce prophylactic measures—the wearing of gowns and masks and observing personal hygiene; the giving of talks, stressing the dangers of tuberculosis, and urging attendants to take rest when ill.

The value of roentgenography is especially

emphasized. It is appreciated especially for patients who have been subjected to shock therapy.

Of the tuberculous patients 66.4 per cent were dementia praecox cases; 10.2 per cent, manic depressives; 3.8 per cent, arteriosclerotics; 2.4 per cent, mental deficiency cases. Most of these were diagnosed as having tuberculosis after being in the institution from five to fifteen years. The group between the ages of thirty and sixty were the most frequently afflicted. There were only 2 cases of tuberculous meningitis. Tuberculous enterocolitis, epididymitis, and laryngitis occurred at about the same frequency and with about the same course as among mentally normal patients. Those patients which were the most cooperative seemed to get along the best.

The results with pneumothorax were unfavorable, apparently because of non-cooperation of the patient. Likewise, thoracoplasty was found not to be especially practical—though preferable to pneumothorax.

The author recommends special study of tuberculosis by psychiatrists.—*A. A. de Lorimier.*

Herrick, W. W., Tyson, T. Lloyd, and Watson, B. P. Association of hydrothorax with ovarian fibroma (Meigs's syndrome). *Arch. Int. Med.*, March, 1943, *71*, 370–376.

The authors present this case in order to call attention to the significance of the combined thoracic, abdominal and pelvic features. The literature on this subject has been summarized by Meigs* under whose name the syndrome is now classified.

The case presented here is that of a woman, aged seventy-five, with a history of five normal pregnancies. Three months after the patient came under observation there was found to be edema of both feet, clubbing of the fingers was noted, there was persistent anemia of the secondary type, and unequivocal signs of fluid were found at the right base. The first thoracentesis produced 1,000 cc. of clear, straw-colored fluid. The specific gravity was 1.021. A stained smear of the centrifugate showed a moderate number of red blood cells, 10 to 15 small mononuclears per high power field and a few large mononuclears. No polymorphonuclear leukocytes were seen nor cells containing mitoses. Cultures showed no growth. Guinea pig inoculations gave negative results. During the following fourteen months nine aspirations, each of 1,000 cc., were performed. Aspiration was done whenever dyspnea, marked thoracic discomfort and the physical signs of an appreciable amount of exudate demanded the procedure. Careful observation of the temperature during this time revealed no fever.

A pelvic examination revealed a tumor in the right side of the pelvis, freely movable between the hands and somewhat suggestive of an ovarian enlargement. At no time were there convincing signs of ascites. At operation, the large tumor was found to involve the right ovary, which had a narrow pedicle. The left ovary was the seat of the smaller tumor and also had a narrow pedicle. Both pedicles were clamped and the ovaries removed.

Convalescence was uninterrupted. The last aspiration of the chest was done two days before the laparotomy, 1,100 cc. of fluid being removed with a small residue remaining. Postoperatively the signs of the remaining fluid appeared within a week. There has been no recurrence of the pleural fluid.

Thus far there has been no satisfactory explanation of the association of ovarian fibroma with hydrothorax and ascites. The possibility of an abnormal communication between the two serous cavities may be dismissed since the amount of fluid in one cavity is not influenced by removal of fluid from the other. That a low level of serum protein is concerned seems unlikely. If accumulation of fluid in the serous cavities was a result of diminution in serum protein, edema of the subcutaneous tissues should be present. Although noted in this case it was slight and transitory, while in most reported cases it was not observed.—*J. J. McCort.*

Gordon, Burgess, Charr, Robert, and Savacool, J. Woodrow. Pleural effusions in pulmonary tuberculosis. *Am. Rev. Tuberc.*, Jan., 1943, *47*, 35–40.

Eighty selected cases of pleural effusion were studied at the Chest Department of the Jefferson Hospital (Philadelphia) and the Whitehaven Sanatorium; autopsies were performed in 35 of these. The postmortem studies included injection with radiopaque substance and roentgenography to determine the [illegible] and characteristics of the blood vessels.

In 20 of the necropsied cases, the fluid was

* Meigs, J. V. Fibroma of the ovary. *Ann. Surg.*, 1939, *110*, 731–754.

non-purulent—serous, serofibrinous or hemorrhagic. Tubercle bacilli were found, by direct culture or by sedimentation, in all of these. The pleural surfaces showed a fibrinous exudate and loss of the normal lustre. Superficial tubercles were common, especially along the anterior surface of the lung. The posterior surfaces of the lung showed congestion and definitely fewer caseous nodules. Histological studies revealed tubercles in the pleura as well as in the subpleural zones—indicating that the tubercle bacilli likely gained access to the fluid directly.

Clinical studies indicated that, in most instances, the fluid was clear in the beginning and that then it was very difficult to isolate the organisms. As the fluid became more turbid, positive cultures were obtained and bacilli were found in the sediment. Acute congestion of the pleura and subpleural zones was found in cases of hemorrhagic effusions. These vascular changes apparently occurred prior to caseation—leading the authors to believe that hemorrhagic effusion is probably a precursor to caseation. They believe that hemorrhagic effusion leads to pleural thickening and, thereafter, subsidence of the congestion, and to a non-hemorrhagic effusion.

In areas of caseation, the blood vessels were narrow (arterioles showing definite thrombi and some of the branches being obliterated). With caseation, the vessels were squeezed flat and held empty; ischemia existed in the nodules—resulting in liquefaction and cavity formation.

Long continued effusion seemed to produce a diffuse fibrosis, with sclerosis of the vessels and a generalized ischemia of the lung. The fibrosis was especially marked in the peripheral regions. Regardless, caseation continued—contradicting therapeutic value of splinting the lung by the fluid. It is suggested that, instead, the fluid might produce permanent atelectasis, with bronchiectasis, abscess and other complications.

It is emphasized that tubercles located in the anterior part of the lung show a definite tendency to rupture, probably due to the greater thoracic movements in the anterior chest. Though thoracocenteses may result in decreased lubrication between the moving surfaces of the parietal and visceral pleurae, and though such measures may lead to sinus formations and secondary infection, the authors recommend repeated aspirations of the fluid. They use an 18 gauge curved needle and they suggest that secondary infection be counteracted by the use of sulfadiazine. The aspiration should be accomplished in the posterior axillary line (to minimize the pain and to counteract the possibilities of perforating tubercles which are more numerous in the anterior chest). Following each aspiration, the patient should lie on the opposite size for one or two hours, thereby permitting the needle tract to close.—*A. A. de Lorimier.*

Sweany, Henry C., Levinson, Samuel A., and Stadnichenko, A. M. S. Tuberculous infection in people dying of causes other than tuberculosis. *Am. Rev. Tuberc.*, Sept., 1943, *48*, 131–173.

The authors speak of the enigmatic status of knowledge relative to the source and early course of tuberculous infections. The object of their study was to reconsider the incidence of active tuberculous lesions in people who are apparently well; likewise, among ill people who had no recognized symptoms or the diagnosis of tuberculosis; to consider the mode of development—as correlated with age, race, sex, occupation or intercurrent diseases; to study means of identifying dangerous lesions; to consider the condition of the tubercle bacillus in one and another type of lesion and in one and another location of a lesion, and, finally, to consider the most appropriate methods of clinical investigation.

The study included bacteriological, pathological, and roentgenological aspects pertaining to 300 patients who had died of conditions other than tuberculosis but who were found to have lesions in the lungs or related lymph nodes.

Of these, 84.7 per cent were found to have calcifications believed to be associated with tubercles; of this group many had lesions which were too small for satisfactory study but dissection was accomplished of dense lesions removed from 70.7 per cent of the 300 patients. Of these 2.4 per cent had a history or clinical findings of tuberculosis, but no tubercle bacilli were ever demonstrated during life (gross and microscopical evidence was found in 1.9 per cent).

Seventy-five per cent of the lesions which were dissected appeared to be of the primary phase; 23.6 per cent, the reinfection phase;

the rest unclassifiable. Seven per cent of the cases of the first decade showed calcification; 55 per cent of those of the second decade; 82.4 per cent of those of the third, and approximately 100 per cent of those of later decades. Seventeen per cent showed positive cultures, while only 7.6 per cent showed acid-fast bacilli on smears and 2 per cent showed positive smears but negative cultures. In 3 of the cases, tuberculous activity was identified on the basis of pathological evidence of inflammation around the tubercle. In all, 20.8 per cent of the group revealed activity in one way or another.

It appeared that tubercle bacilli are prone to live in or near the outer capsules of tubercles —in microscopical tubercles, in monocytes and giant cells located in close proximity to the main lesions. However, cultures of these regions were usually negative. Positive cultures were obtained in 80 per cent of the tubercles of less than one year of age—with a gradual decrease to an entire negative series of cultures by the end of fifteen years. Fibrosis appeared to be a favorable type of reaction. It seems that widespread lesions develop a higher degree of immunity against the bacilli.

Of the cases which showed "densely calcified" or partially calcified lesions, roentgenographically, 4.3 per cent were identified as chondroma, osteoma, lipoma, fibroma, or phlebolith.

The authors conclude that "clinicians must continue to investigate every clue, roentgenologists must still look for the small, soft flecks and infiltrates or varying types of calcified lesions, and bacteriologists must search for bacilli as they have heretofore."

Softness of a lesion, size, the fuzziness of the borders, and cloudy appearance speak for relatively recent development. Fuzzy, round infiltrates in the apical regions are more prone to harbor living bacilli than are calcified lesions in the bases.

In general, the rather arbitrary criteria utilized by the Army and Navy are considered practical.

Many of the lymph nodes [illegible]

with alarm.

Approximately [illegible] a positive tuberculin reaction [illegible] have positive cultures [illegible] strongest reaction [illegible] living bacilli.

Many of the [illegible] demonstrable tubercle bacilli [illegible] infected districts. Rather than [illegible] they had never been [illegible] speculate that many of them [illegible] lesions, probably progressive [illegible] or that they had extra[illegible] remark that [illegible] tinguish tubercle bacilli [illegible] capsulation within three [illegible] and that by the time [illegible] (in one to two years) the [illegible] are dead (though some may [illegible] conditions for more than [illegible]).

In none of the [illegible] silicosis could there be [illegible] tuberculous activity [illegible] the defense mechanism [illegible] within old nodules.

The various phases of [illegible] are reviewed: invasion [illegible] way of the lungs [illegible] way of the intestine [illegible] tract; [illegible] to three months [illegible] it diminishes [illegible] are dead. [illegible]

[illegible]

origin. Fifteen of these cases showed cavitation and, of these, 12 had positive sputa—though only 1 showed evidence of bronchogenic spread. Otherwise, serial studies indicated a general tendency for hematogenous progression rather than bronchogenic spread among the group having extrapulmonary lesions. This was quite in contrast to the findings among the 100 cases of strictly pulmonary lesions—where progression appeared to be by bronchogenic spread.—*A. A. de Lorimier.*

Lintz, Robert M. Spontaneous mediastinal emphysema. *Arch. Int. Med.*, Feb., 1943, *71*, 256–261.

At the time this paper was written the author had found in the literature only 13 instances of this syndrome occurring spontaneously. Because of the ease with which the diagnosis is made and because of the importance of differentiating spontaneous mediastinal emphysema from various vascular accidents, it was deemed advisable to report this case.

The patient was a twenty-two year old autumobile mechanic. He was admitted to the hospital complaining of severe pain of one hour duration in the chest on the left side. At the time the pain appeared he was sitting quietly in a chair reading a newspaper and stated that he had not done any strenuous work that day. On physical examination there was a definite area of subcutaneous emphysema over the lower portion of the anterior wall of the chest on the left side. Anteriorly from the left costal margin to the third rib 'boiler-like' sounds of loud intensity were heard; extending into the axilla finer crackling sounds were audible. These 'boiler-like' sounds might be compared to the noise that one hears when crumpling a hand full of cellophane close to the ear, and could be heard distinctly several feet from the patient's chest. By the following morning, eighteen hours after admission, all that could be heard were a few crackling sounds over the precordium, appearing only during diastole and heard best with the patient lying on his left side.

The patient felt fine and because he had not had any pain or discomfort since the previous evening insisted on going home.

A roentgenogram of the chest taken at the time of admission showed a small pneumothorax at the apex of the left lung. Other roentgenograms were taken in an effort to discover air in the mediastinum but none could be made out.—*J. J. McCort.*

Adcock, John D. Spontaneous interstitial emphysema of the lung: with mediastinal, retroperitoneal and subcutaneous emphysema. *Arch. Int. Med.*, May, 1943, *71*, 650–657.

A case of spontaneous interstitial emphysema of the lung with extension of air into the retroperitoneal and subcutaneous tissues is reported. This occurred in a sixty-two year old white man who was undergoing fever therapy for central nervous system syphilis. The first change to be noted was a widespread subcutaneous emphysema. At no time did the patient complain of pain and this is thought to have been due to the ease of escape of the air from the mediastinum, which prevented the development of high mediastinal pressure.

A roentgenogram showed evidence of mediastinal air. There was a small density at the base of the left lung which was interpreted as an area of atelectasis. Just above this there was an area of greater penetration which suggested a small area of lung containing a larger than normal amount of air. A small amount of subcutaneous emphysema could be seen in the neck. A roentgenogram was obtained during expiration to make certain that a small pneumothorax was not overlooked and none could be demonstrated. A roentgenogram of the abdomen showed a striking amount of free subperitoneal emphysema. The small area of transient atelectasis was apparently responsible for the development of the interstitial emphysema of the lung in this instance. It was possible to locate clinically the site of escape of air from the alveoli into the perivascular and interstitial tissues of the lung.

The signs rapidly disappeared and eight days later nothing abnormal could be detected on examination of the patient. Another roentgenogram of the chest at this time showed a return to normal with complete disappearance of the small area of density at the base of the left lung and the area of emphysema above it.—*J. J. McCort.*

Huang, Chia-Ssu. Tuberculous tracheobronchitis. *Am. Rev. Tuberc.*, May, 1943, *47*, 500–508.

One hundred and fifteen cases of active pulmonary tuberculosis which were autopsied at the University of Michigan Hospital from July, 1936 to December, 1941, were analyzed with respect to lesions in the larynx, trachea and bronchi. Lesions were found in one or

another of these passages in 50.4 per cent of the group; 42.7 per cent showed tracheobronchial tuberculosis.

The incidence of tuberculosis of the larynx, trachea, and bronchi, with open cavities, was three times as high as that without them. Less than half of the group which showed no extrapulmonary tuberculosis showed these lesions while practically half of those with extrapulmonary lesions showed them. Of the latter, intestinal tuberculosis was the most common type. Only 1 case out of 7 having negative sputa showed these lesions.

Histopathologically, the lesions were differentiated as ulcerated or as non-ulcerated (discrete submucosal tubercles or diffuse tuberculous granulation). About two-thirds of the lesions were ulcerated.

The author believes that tuberculous tracheobronchitis is, in most cases, brought about by the direct invasion of the mucous membrane or mucous glands by tubercle bacilli directly from the cavernous lesions in the lungs.—*A. A. de Lorimier.*

BOBROWITZ, I. D. The round pulmonary tuberculous focus. *Am. Rev. Tuberc.*, May, 1943, *47*, 472–483.

The author has been interested in "round foci," "solitary foci" or "circular lesions" as found in a series of 55 tuberculous patients. These lesions were reviewed roentgenographically and by clinical records.

Usually these foci were found in the infraclavicular region and within the area of the first anterior intercostal space; in only 4 instances, in the apex; occasionally, in the third interspace. No basal lesions were observed. The foci were sharply marginated in 70 per cent of the cases; surrounded by fine nodules or infiltration, in the others. Likewise, 70 per cent had a negative sputum (though 15 per cent of these had a history of positive findings). In 1 case, the history described a cavity at a site where the round focus was identified and in 3 patients, the round lesions were present in re-expanded pneumothorax lungs (where the pneumothorax had been instituted because of cavitation). In 3 of the patients, the round foci developed in regions where previously there had been no evidence of parenchymal changes. All of these lesions gradually contracted, though one of them showed an intermediary stage of enlargement and a suspicious area of clearing.

In 7 of the patients, the round foci developed with spontaneous closure of cavities (which had persisted for seven months as an average). All but 1 of these patients had positive sputum.

The author attributes the development of most round foci to obliterative phenomena concerned with cavitations. Though he considers these lesions to be relatively benign, he cites the warning that they may produce cavitation and that they must be carefully watched.—*A. A. de Lorimier.*

BOGEN, EMIL, and ROGERS, ARTHUR. The scaphoid scapula in tuberculosis. *Am. Rev. Tuberc.*, March, 1943, *47*, 303–307.

The configuration of the vertebral border of the scapula has been evaluated with respect to 100 patients at the Olive View Sanatorium (California), by physical examination and by routine roentgen studies. The authors found definite predominance of a straight or a concave border among these patients. Only 23 per cent showed a convex border.

They call attention to the conclusions described by Graves—that the straight or the concave configuration of the vertebral border of the scapula is found mainly among individuals who are poorly adaptable, peculiarly vulnerable, and unduly susceptible to disease; they being the constitutionally inferior and the short-lived individuals of the race.

Graves had described a progressive increase in the incidence of the convex configuration, in accordance with age—65 per cent of all scapulae at ten years being scaphoid whereas by the eight decade, only 20 per cent were of this type. He accounted for this difference on the basis of early death of the individuals with this type. However, the authors lean to Wolff's law and Steindler's dicta—that "the form and architecture of bone corresponds mathematically to the physical demands of external stresses." They suggest that the activity of the levator scapulae may be especially concerned in changing the configuration of the vertebral borders from concave to convex.—*A. A. de Lorimier.*

SIMS, J. L. Multiple bilateral pulmonary adenomatosis in man. *Arch. Int. Med.*, March, 1943, *71*, 403–409.

A pulmonary lesion of sheep, apparently of infectious origin, but resembling a tumor in its morphologic characteristics has been known since about 1891. It has received such varying

names as jagziekte, epizootic adenomatosis, pulmonary adenomatosis and infectious adenomatosis. Very similar and probably identical conditions have been reported under the titles of verminous pneumonia and Montana progressive pneumonia of sheep. A considerable incidence has been found in areas as widely separated as South Africa, Saxony, England, Iceland and Montana.

A case of pulmonary adenomatosis in man resembling somewhat the disease of jagziekte as found in sheep is presented. Roentgen examination of the chest showed some soft patchy mottling throughout the left middle and lower lung fields, although no large areas of consolidation were seen. On the right there was a great deal of soft opacity, almost completely obscuring the aerated lung except for some air in the apex and peripherally at the base. The patient died and an autopsy was performed. When the chest was opened the right lung was quite heavy and felt firm; it was subcrepitant and full of irregular nodules beneath the pleura. The cut surface was in most areas pinkish-yellow, smooth and meaty in appearance with fine strands of gray-white tissue separating great numbers of closely packed round and polygonal nodules of a few millimeters to several centimeters in diameter. The left lung showed similar but much less extensive nodularity beneath a perfectly smooth pleura and was generally subcrepitant to crepitant. The trachea and bronchi were filled with a frothy, brownish fluid and their mucosa was somewhat injected.

On microscopic study the nodules seen grossly seemed to be formed by portions of lung tissue which contained their normal alveolar skeleton. The normal alveolar epithelium had been replaced by high cuboidal and columnar cells. Generally the alveoli were lined by only a single layer of cells; in one or two isolated spots there seemed to be a slight anaplastic tendency with the formation of tiny nests of polyhedral cells within an alveolar lumen. The epithelial cells themselves possessed a granular cytoplasm, staining moderately heavy with eosin and a large vesicular nucleus usually located just below the middle of the cells but occasionally at either end.

Current opinion suggests that jagziekte is an infectious disease possibly of virus origin. A few similar human cases have been previously reported, so that it would seem that multiple, bilateral pulmonary adenomas may occasionally develop in man resembling morphologically those found in the ovine disease mentioned. While the evidence to support it is slight, there must be considered the possibility that this lesion as seen in sheep possesses neoplastic characteristics as well as transmissibility. The identity of the condition found in man with that found in sheep is not established by available evidence but further investigation seems indicated when opportunity presents.—*J. J. McCort.*

ROENTGEN AND RADIUM THERAPY

Maino, Charles R., and Mussey, Robert D. Carcinoma of the cervix coincident with pregnancy. *Am. J. Obst. & Gynec.*, Feb., 1944, *47*, 229–244.

A study of 3,570 cases of carcinoma of the cervix observed at the Mayo Clinic in approximately thirty-two years revealed that pregnancy was present in 26, or 0.7 per cent, of these cases when the carcinoma was found. The following statements are included in a summary of the study of these 26 patients.

1. The average age of the patients in the 26 cases in which carcinoma of the cervix was coincident with pregnancy was 32 years. The youngest patient was twenty-five years of age and the oldest patient was forty-one years of age. The prognosis was no worse in the case of young patients than it was in cases in which the patients were older.

2. The average number of previous pregnancies was 6 and the average number of children was 4. The number of pregnancies apparently did not affect the prognosis. In cases in which the carcinoma was diagnosed in the later months of pregnancy, the lesion usually was well advanced and the prognosis was poor.

3. Pregnancy may occur after carcinoma of the cervix has developed. A family history of carcinoma was elicited in 7, or 35 per cent, of the 20 cases which were observed five or more years prior to 1941. The prognosis in these 7 cases was better than the prognosis in the remaining cases.

4. Bleeding was the initial symptom in 23, or 88.5 per cent, of the cases. In 25 per cent of the cases, the patients did not realize that they were pregnant when the diagnosis was made.

5. No definite conclusions can be drawn con-

cerning the relative value of radiation therapy: however, it appears that operation is preferable in cases in which the lesion is operable and that supplementary irradiation increases the percentage of good results. This is in contrast to the relative value of radiation therapy and hysterectomy in cases of carcinoma of the cervix in which the patients are not pregnant.

6. The authors are in general agreement with Strauss concerning treatment of carcinoma of the cervix coincident with pregnancy. If the extent of the lesion permits operation and if the fetus is not yet viable, total hysterectomy is followed by irradiation; if the lesion is operable and the fetus is viable, cesarean section is followed by panhysterectomy and postoperative irradiation.

7. In cases in which the lesion is non-operable and the fetus is viable, cesarean section is followed by irradiation; in cases in which the lesion is nonoperable and the fetus is not yet viable, sufficient irradiation is employed to treat the lesion; incidentally, abortion occurs.

8. In cases in which the lesion is operable, total abdominal hysterectomy has produced the best results. In 57 per cent of the cases in which this procedure was employed, the patients were free of recurrence five years after the operation.

9. In this series of cases of carcinoma of the cervix coincident with pregnancy, many of which were observed before the present methods of treatment were developed, the prognosis appeared to be at least as favorable as the prognosis of carcinoma of cervix that is not associated with pregnancy. Of the 20 patients who were followed, 30 per cent were free of recurrence five or more years after they had been treated at the Clinic.—*Mary Frances Vastine.*

Sandler, Bernard. A preliminary note on the planning of combined radiotherapy of carcinoma cervix uteri. *Brit. J. Radiol.*, Nov., 1943, *16*, 331–337.

Charts and diagrams are given of a proposed method for combining roentgen and radium irradiation in the treatment of carcinoma of the cervix. An attempt is being made to develop a routine procedure. These preliminary investigations are only a first step towards a practicable solution of the problem of accurate radiotherapy in the pelvis. It is not yet ready for use as a routine procedure but a study of the charts and diagrams will show what has been accomplished so far. Further work is being done in an attempt to perfect the method.—*Audrey G. Morgan.*

Behney, Charles A., and Howson, John Y. Carcinoma of the cervix, end results. *Am. J. Obst. & Gynec.*, April, 1944, *47*, 506–513.

This report, based on the histories of 580 patients suffering from carcinoma of the cervix, demonstrates the value of high voltage roentgen therapy in the treatment of this disease. The importance of the later observations is enhanced by comparing these results with those of an earlier report concerning 437 patients; a grand total of 1,017 women suffering from cancer of the cervix, who died on the radiologic service of the Philadelphia General Hospital since 1922. Stage IV lesions, treated with external irradiation of high voltage roentgen therapy alone, lived longer than those treated with lightly filtered radium alone. The best results, however, were secured in the group, who, after regression of the primary lesion had been brought about by preliminary high voltage roentgen therapy, were subsequently treated with heavily filtered radon at a distance of 1 cm. Since this fact became apparent, it has become the authors' policy to administer external high voltage roentgen therapy preliminary to the radon application in every case of carcinoma of the cervix. The longer duration of life in patients in the recent series who were treated with high voltage roentgen therapy, regardless of the stage of the disease, can probably be attributed to the fact that these were given more adequate dosage than those of the earlier study.

Summary

1. When the general condition of the patient permits, every case of carcinoma of the cervix should be treated with some form of radiation therapy.

2. External high voltage roentgen therapy is always beneficial and safe for even the most advanced stages of the disease.

3. In many apparently advanced lesions, preliminary roentgen therapy will result in sufficient regression of the lesion that radon may be subsequently applied to great advantage.

4. Heavily filtered radon applied at a distance of 1 cm. results in better palliation than the highly filtered radon in contact application.

5. By observing the duration of life after admission to service in patients who died from

tus necessary is a common centimeter ruler. The method of making the measurement and the working out of the geometrical equation for the figure are given.—*Audrey G. Morgan.*

Lea, D. E. The spatial distribution of ionization in irradiated tissue and its relation to biological effects. *Brit. J. Radiol.*, Nov., 1943, *16*, 338–339.

Experiments in the production of chromosome aberrations in irradiated microspores of *Tradescantia* are described which seem to show that the spatial distribution of ionization in irradiated tissue is definitely related to biological effects. A curve of anticipated efficiency (for equal ionization in tissue) of roentgen-ray wavelengths ranging from 1 to 10 A has been constructed. The predictions based on these calculations were tested by making irradiations at wavelengths 0.15, 1.5, 4.1 and and 8.3 A. The agreement obtained was satisfactory.

This type of action is a direct action of irradiation and must not be confused with the indirect type in which the radiation ionizes some common cell constituent, probably water, activating the water, and the activated water then produces the biological effect. The spatial distribution of ionization is best understood in the direct type of action.—*Audrey G. Morgan.*

Goldmann, Carl H. Tomographic attachment suitable for most x-ray plants. *Brit. J. Radiol.*, Nov., 1943, *16*, 355–356.

Deep-seated abscesses which are hard to locate are common among soldiers in tropical Africa. The special tomographic equipment cannot be used in military hospitals. Twining and Bush have designed tomographic attachments which, however, have the disadvantage that they must be used with the patient lying down and also that there is a rigid combination between the Potter-Bucky diaphragm and the tomographic movement levers.

The author describes and illustrates an apparatus by means of which tomography can be carried out with almost any existing roentgen-ray apparatus with the patient in either the horizontal or vertical position, and with or without a mobile or stationary grid. It is simple in structure, cheap, small in size and light in weight. While the results are not, of course, equal to those of the special tomographic equipment, they compare favorably with those obtained by the Twining and Bush attachments. It has been used successfully for localizing deep pulmonary and liver abscesses, encysted effusions and for the localization of nonmetallic foreign bodies. There is a small depth gauge for determining accuracy of depth.—*Audrey G. Morgan.*

Nettleship, A. Tissue changes produced in C3H mice by 50 r whole body exposure. *Radiology*, Jan., 1944, *42*, 64–70.

Little attention has been paid to the effects of small doses of roentgen rays. The author therefore irradiated C3H mice from an inbred colony with 50 r applied to the whole body and studied the effects. The effects on the blood picture are shown by curves and photomicrographs of the effects on the tissues are reproduced. The blood showed a transitory leukocytosis followed after eight to twelve hours by a mild but persistent lymphopenia. The tissue cells showed swelling and eosinophilic staining of the cell cytoplasm with decreased staining of the nuclei; later slight hyperchromia of the cell and nucleus with final return to normal. There was destruction of cells in the lymph node follicles followed by a slight hyperplasia. Changes in the bone marrow were less pronounced and occurred later than those in the lymph nodes. There was edema of the mucosa of the lower ileum. There was destruction of spermatogenic cells and a reduced rate of mitosis with slow return to normal.

As these changes are only slight they may be regarded as threshold effects of irradiation. The different effects appeared at different times and lasted for varying periods. The damage suffered was mild and there was an early return to normal.

It is evident that definite changes are caused by doses as low as 50 r applied to the whole body of the mouse. A lymphocyte count of the peripheral blood will show threshold tissue damage due to irradiation when a leukocyte or neutrophil count fails to show it.

In the discussion Dr. Henshaw called attention to the fact that a dosage of 50 r may easily be received by roentgen-ray workers and that the cumulative effect of such doses may cause serious injury.—*Audrey G. Morgan.*

Hilding, A. C. The role of ciliary action in production of pulmonary atelectasis, vacuum in the paranasal sinuses, and in otitis media. *Ann. Otol., Rhin. & Laryng.*, Dec., 1943, *52*, 816–833.

In the article, the author describes the experiments which he performed, some at the University of Wisconsin in the Department of

Pathology and others in the Institute of Experimental Medicine. He includes the following observations in the summary:

1. The steps in the development of postoperative pulmonary atelectasis are about as follows:

a. An excess of secretion is formed within the affected lobe.
b. A succession of occluding masses, or pistons, of mucus form across the lumina of the air passages.
c. These "pistons" move up the cylindrical air passages by ciliary action, each carryin a quantity of air.
d. As soon as the pressure within the lobe begins to fall, it shrinks by its own elasticity and from pressure by adjacent lobes.
e. The adjacent lobes carried by the force of inspired air move into the space relinquished by the affected one.
f. The advancing pistons rupture serially as they reach tubes of greater diameter and meet more forceful changes of air pressure. Each then releases the bubble of air which it carried and continues on its course as a mural mass of film.
g. A negative pressure of considerable proportion is produced within the lobe when the supply of air is exhausted.
h. The masses of secretion then present in the air passages come to a standstill when cilia can no longer advance them against atmospheric pressure.
i. The cilia continue to remove secretion from these "stalled" masses in thin films and might eventually remove them entirely if they were not replaced by continued secretion.

2. Negative pressure can be produced within a normal sinus by the introduction of a quantity of mucus which replaces a portion of the contained air. When sufficient mucus has reached the ostium by ciliary action to completely fill it so that incoming air cannot pass by, negative pressure develops in the sinus. The pressure falls as the mucous mass is progressively dragged and pushed through the ostium. When the effective power of the cilia is equalled by the difference between atmospheric pressure and the pressure within the sinus, the mass ceases to advance and the pressure ceases to fall. The cilia continue to act and remove the mucus in thin films. When sufficient mucus has been removed, atmospheric pressure forces air through the ostium into the sinus again.

Negative pressure almost certainly develops clinically in sinuses when they are more or less filled with mucus and when their cilia are active.

3. The negative pressure, which is known to occur within the middle ear, is probably due to the force of ciliary action moving mucus down the eustachian tube.—*Mary Frances Vastine.*

Burrows, Harold, and Clarkson, J. R. The role of inflammation in the induction of cancer by x rays. *Brit. J. Radiol.*, Dec., 1943, *16*, 381–382.

Early in this century cancer developed on the hands of many radiologists and technicians. This led to a study of the factors that might help in the production of such cancerous growths. The authors describe experiments made on rabbits to determine whether inflammation played any part in the causation of such tumors. They produced inflammation in the groins of 18 rabbits and gave them a single irradiation of 600 or 2,000 r. Sarcoma developed at the site of irradiation in 13 of these 18 rabbits. Only those rabbits which survived irradiation for as long as twenty-two months are considered. Twelve rabbits were irradiated with the same doses without any preceding inflammation; tumor did not develop at the site of the irradiation in any of these animals nor in any of those that were irradiated with a dose of only 250 r. Nine guinea pigs were similarly irradiated and cancer did not develop in any of them, no matter whether they had previous inflammation or not.—*Audrey G. Morgan.*

Mitchell, J. S. Metabolic effects of therapeutic doses of x and gamma radiations. *Brit. J. Radiol.*, Nov., 1943, *16*, 339–343.

Experiments are described and the results summarized which show that significant disturbances of both carbohydrate and nucleic acid metabolism are produced by therapeutic doses of roentgen and radium irradiation, probably by means of inactivation of enzymes. Tables showing the detectable effects of roentgen and radium irradiation are given.—*Audrey G. Morgan.*

Fleming, J. A. C. Investigations into the degree of scattered radiation received by x-ray workers during routine diagnostic examinations in a military hospital department. *Brit. J. Radiol.*, Dec., 1943, *16*, 367–370.

If an operator does not expose himself to

the direct beam from a roentgen tube, the chief source of radiation to which he is exposed is scattered radiation from the body or part of the patient through which the roentgen-ray beam is passing. With a view to determining the amount of such radiation, experiments were carried out at a military hospital, the measurements being made with a Hammer dosimeter with a special ionization chamber which has been described before.

The measurements showed that under normal working conditions a roentgenographer unprotected by any lead screen or other protective device can safely stand at a distance of $2\frac{1}{2}$ feet or more from the center of the field of irradiation in the patient; at this distance he will not receive an overdose of scattered radiation from the body of the patient. When roentgenograms are taken during fluoroscopic examination the operator should stand about 5 feet from the center of the field of irradiation while the roentgenograms are actually being made. This is not necessary if the greater part of the body of the operator is protected by a lead screen or apron.—*Audrey G. Morgan.*

Ungar, E. M. Efficiency of radiation and homogeneity. *Brit. J. Radiol.*, Dec., 1943, *16*, 376–380.

Since the introduction of radiotherapy there has been a constant effort to improve the therapeutic effects of irradiation of deep tumors. Mayneord and Happey have suggested rules for applying the integral dose throughout the tumor irradiated. It has been found that homogeneity of the tumor dose throughout the tumor is desirable for in this way the required minimum tumor dose can be applied throughout the growth. If the fields used are too large and a homogeneous dose is given throughout the tumor the integral dose will be too high. If the size of the fields is reduced and their shapes adapted so as to cover the tumor adequately and homogeneity is achieved it leads to great economies in the integral dose. The reduction of field size is limited by the fact that every single field should cover the whole tumor volume and by the degree of accuracy possible in estimating the size and location of the malignant growth; that is, the less precise the knowledge of its extent, the larger the fields must be in proportion to the size of the tumor. Diagrams and formulae used in the working out of these propositions are given and also diagrams of a case of carcinoma of the cardia illustrating the effect homogeneity has on economy of irradiation in practice.—*Audrey G. Morgan.*

Roberts, J. E., and Farmer, F. T. An x-ray output meter. *Brit. J. Radiol.*, Nov., 1943, *16*, 353–354.

The technique of measuring a beam of roentgen rays at the opening of the tube has been utilized in some therapy equipments but these instruments have, as a rule, been quite delicate and have not proved as reliable as necessary for clinical work. An instrument is described which seems to meet all requirements at a minimum of cost and equipment.

The basis of the instrument is an ionization chamber fitted into the tube aperture through which the rays pass. The current through the chamber, when saturation is maintained in it, is then a measure of the intensity of the beam. A simple robust valve voltmeter system is used. The circuit is illustrated and the ionization chamber and the temperature compensation system described in detail. For reference purposes this instrument is called the M. H. x-ray output meter.—*Audrey G. Morgan.*

Williams, Marvin M. D. Recovery of radium tubes from sewer. *Radiology*, Nov., 1943, *41*, 478–482.

Three small tubes of radium each containing approximately 50 mg. radium sealed inside a glass tube which was in turn sealed inside a tube of monel metal were removed from a patient and misplaced. Their loss was not discovered until an hour later. The hospital rooms and grounds were checked with a portable Geiger-Müller counter and then the hospital and city sewers checked. The tubes were not found and then sewer scrapers which are illustrated were used. Finally a wadded-up truck tire chain was dragged through the sewer and one of the tubes found six weeks after their loss. The sewer scraper was then pulled through the same section of sewer and the second tube located. But the third could not be found. An electrometer was then used and the approximate position of the third tube determined and it was then removed with a smaller scraper. There was a deposit that looked like coal-dust in this section of the sewer that had caught the tube and prevented its being removed by the larger scraper.

Other possible methods of locating radium in sewers are discussed.—*Audrey G. Morgan.*

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ROENTGENOGRAPHIC INTERPRETATION OF ACUTE HEMATOGENOUS OSTEOMYELITIS TREATED WITH PENICILLIN*

By W. A. ALTEMEIER, M.D., *and*
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CINCINNATI, OHIO

PENICILLIN has revolutionized the management of acute hematogenous osteomyelitis.[1] The spectacular control of the bacteriemia, the bony infection, and the metastatic visceral infectious complications has produced a radical reduction in morbidity as well as mortality. This control of the infection has been so effective that emergency surgical decompression of the area of involved bone has not become necessary except in fulminating cases. Instead, the required surgery has usually been limited to incisions and drainage of abscesses developing in soft tissues and to the removal of selected large and unabsorbed sequestra. The disfiguring sequelae such as deformity, limp, draining sinuses, or ankylosis of adjacent joints have been largely eliminated. Likewise, a careful study of the cases treated with penicillin has forced us to modify our earlier conceptions and interpretations of the roentgenographic changes occurring in acute hematogenous osteomyelitis.

MATERIAL

During the past twenty-seven months we have observed the results of treatment with penicillin in 52 cases of acute hematogenous osteomyelitis. The group included 44 cases of acute hematogenous osteomyelitis of the major long bones, some of which also had involvement of the flat bones of the pelvis. In addition, there were 4 cases with involvement of the pelvic bones only. The responsible etiologic agent was determined in every instance but 4, and was found to be the hemolytic *Staphylococcus aureus* in 42 cases, the non-hemolytic *Staphylococcus albus* in 3, the hemolytic streptococcus in one, and the pneumococcus type III in one.

METHOD

All of the cases were treated primarily with penicillin although 28 of the patients had received a limited amount of sulfonamide therapy before penicillin was started. In 9 of these, penicillin and sulfadiazine

* From the Departments of Surgery and Radiology of the University of Cincinnati and the Cincinnati General Hospital. The work described in this paper was done under contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and the University of Cincinnati.

were given concurrently. Many of the early cases received less than 800,000 units and the results were usually very good. Experience, however, has shown[1] that a total dose of 1,500,000 or more units administered over a period of approximately three or more weeks is a desirable dosage. The penicillin was usually administered intravenously or intramuscularly in amounts of 15,000 to 25,000 units at intervals of three hours. In some instances, it was administered by continuous intravenous drip when 30,000 to 80,000 units in 2,000 cc. of physiological saline solution were administered at a rate of 25 to 30 drops per minute. The dose was reduced when it was apparent that the infection was well controlled. Surgery was withheld whenever possible and was usually limited to incision and drainage of large abscesses developing in neglected or misdiagnosed cases. If small abscesses developed, their contents were aspirated with a syringe and needle, and the abscess cavity was partially refilled every two or more days with a solution of penicillin in physiological saline containing 5,000 units per cubic centimeter.

The clinical response to treatment and the roentgenological changes in the involved bones which developed subsequently were carefully observed.

RESULTS

Under the therapy outlined, all cases recovered but one of severe and neglected acute hematogenous osteomyelitis of the tibia with staphylococcus pneumonia and bacteriemia which was admitted in moribund condition and died seventeen hours later. The mortality rate was therefore remarkably low, being only 1.9 per cent. There was also a striking reduction of the period of morbidity.

The clinical results obtained fell into four groups and varied with the duration of the disease, the onset and adequacy of penicillin therapy, and the severity of the infection.

Group I. If the correct diagnosis was made early, within the first two or three days, and adequate treatment was started immediately, the results were truly excellent (example: Case 17). After a period of approximately thirty-six to seventy-two hours the fever, rapid pulse, bacteriemia, and other general signs of the severe infection began to disappear. At the end of a week, the temperature was usually normal, and the patient looked and felt quite well. The local signs of infection such as tenderness, edema, and redness also began to recede after a similar latent period of thirty-six or more hours. In this group immobilization by means of a plaster cast seemed to be of comparatively little importance, and there was an early return of function. In fact, it was practically impossible to keep some of the children off of the involved extremities as early as two weeks after the beginning of treatment. Surgical intervention was not necessary in this group unless an abscess formed.

The bony changes as depicted on the roentgenograms were minimal, consisting of areas of localized periosteal reaction, small areas of patchy decalcification of the underlying cortex, little or no evidence of sequestration, and ultimate reconstitution of the bone. These findings were hard to see in some instances and were temporarily overlooked at times. An additional 3 cases with typical symptoms and signs of acute osteomyelitis which were treated successfully with penicillin were not included in the report since it was impossible to prove the diagnosis in the absence of roentgenographic findings.

Case 17. B. S., female, aged four, was admitted to Children's Hospital on June 5, 1944, complaining of severe pain in the right leg and high fever of two days' duration. Two weeks before, she had developed a blister on her heel which had become infected.

Examination showed a severely ill white child with marked swelling, tenderness and local heat above and below the right knee. On the right heel an infected superficial ulceration was healing satisfactorily. The white blood count was 16,500 cells per cubic millimeter with 79 per cent polymorphonuclear leukocytes.

The blood culture was positive for the hemolytic *Staphylococcus aureus* on June 5 and 7, 1944.

Roentgenograms (Fig. 1) taken at the time of admission showed no evidence of osteomyelitis. A clinical diagnosis of acute hematogenous osteomyelitis of the tibia and femur was made. The patient was placed on parenteral penicillin therapy giving 15,000 units every three hours at the beginning of treatment and 10,000 units at the same interval later. A small fluctuant area developed over the upper end of the tibia and this was aspirated on June 11, 1944. Thin, watery pus containing the hemolytic *Staphylococcus aureus* was obtained. Two days later this abscess was incised, liberating the purulent material and the leg was immobilized in a plaster cast. The patient's condition improved rapidly thereafter. During the course of illness two transfusions were given and a new cast was applied on July 26, 1944. Roentgenograms two months later showed thickening of the periosteum over the lower third of the right femur and upper third of the right tibia, with a small area of demineralization of the tibia just below the epiphyseal line (Fig. 1). Five months after the onset of the disease, roentgenograms showed practically complete healing of the bone. Her general condition was very good and she had no symptoms or signs of residual bony infection. Her clinical recovery was excellent and the bony damage minimal. In the light of our later experiences, incision and drainage of this small abscess was probably unnecessary.

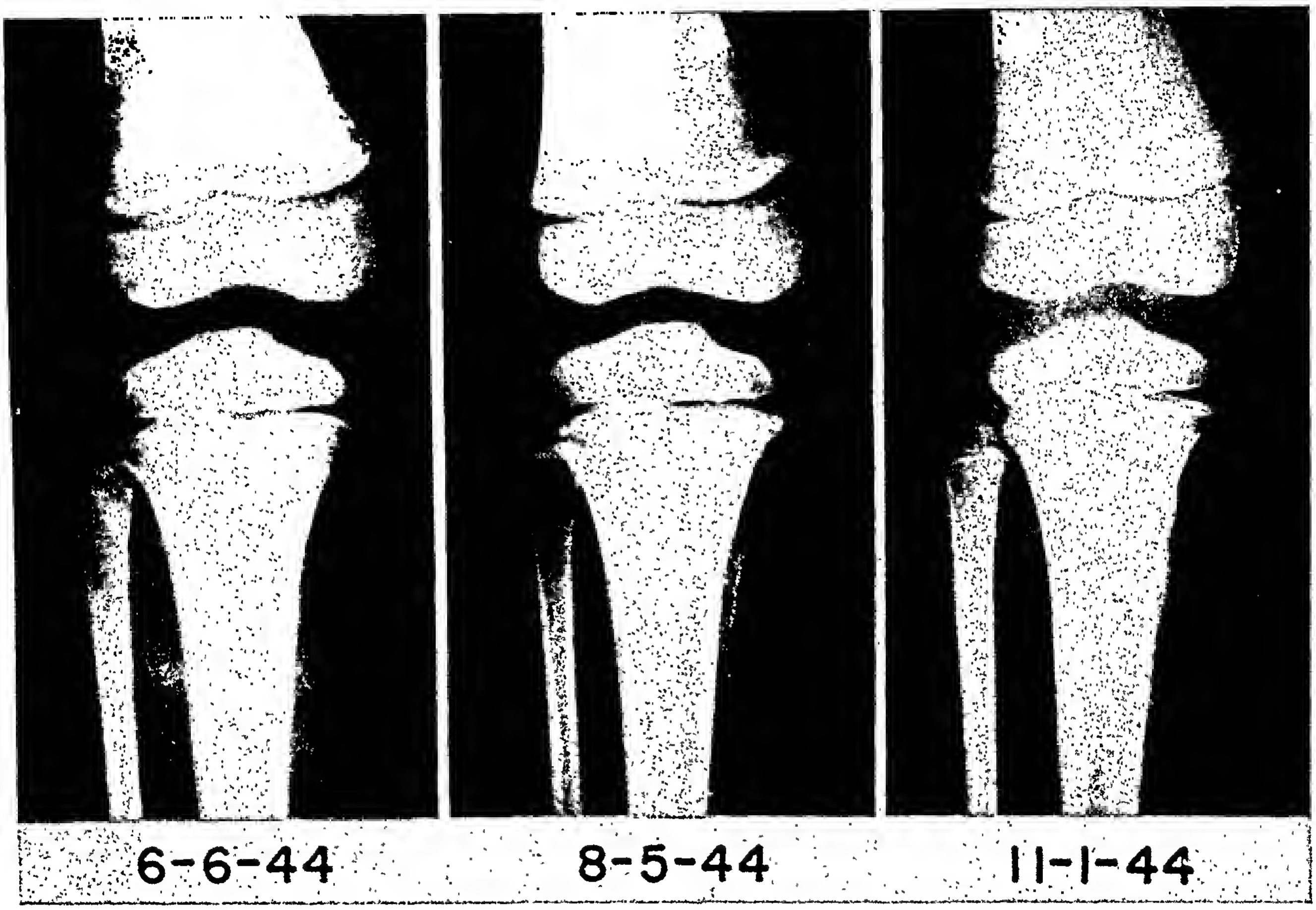

Fig. 1. Showing the bony changes occurring in Case 17. 6-6-44. No evidence of osteomyelitis or periostitis. 8-5-44. Considerable periosteal elevation, upper third of tibia. Mottling of bone just below epiphyseal line due to early bone involvement. 11-1-44. Practically complete healing of periosteum. Cortical infection at upper end has healed. No break has occurred in the cortex and no sequestration has taken place.

Group II. When the diagnosis and treatment with penicillin were moderately delayed, the general and local infections were brought under control less promptly after a period of two, three or more days during which little or no clinical response was evident. In this group local soft tissue abscesses developed more frequently. When small, they were treated successfully by aspiration of their contents and local injection of a solution containing 5,000 units

of penicillin per cubic centimeter at intervals of two or more days. If the abscesses were large, surgical drainage by incision was done to liberate the accumulated necrotizing bacterial toxins and to minimize further tissue destruction. When surgical drainage was carried out for large abscesses, the fall in temperature was usually prompt and not delayed for thirty-six or more hours as in the cases treated without surgical drainage.

The bony changes developing in these cases were of great interest. Usually none was visible on the roentgenograms at the beginning of treatment. After a week or more had elapsed, periosteal reaction and localized patchy demineralization of the underlying bone became evident and increased progressively in extent and degree, becoming most marked one to five months after the onset of the infection. Recalcification of the demineralized areas followed with re-establishment of a normal or nearly normal appearance of the bone. Sequestration did occasionally occur in this group.

Case 4. K. M., white male, aged thirteen, was admitted to the Children's Hospital on October 26, 1943, complaining of pain in the left ankle and right knee of four days' duration. A furuncle had been present on the left elbow for one week, and five days before admission he had turned his left ankle while playing. The following day he had a shaking chill followed by fever and malaise and painful swelling of the left ankle occurred on the following day. Twenty-four hours later the same changes appeared in the right knee.

Examination showed an acutely and severely ill boy whose temperature was 102.5° F., pulse 130, and respirations 48. A large furuncle was present on the left elbow and numerous petechiae covered the trunk and extremities. Many râles were heard throughout both lungs, and the mucous membrane and nail beds were cyanotic. There was increased heat, marked swelling and exquisite tenderness about the left ankle and the lower half of the left leg. Limitation of motion of the right knee with swelling and tenderness over the lower medial aspect of the right thigh was present.

The red blood count was 4,300,000 cells per cubic millimeter and the white blood count was 11,750 cells with 79 per cent polymorphonuclear leukocytes. Urinalysis showed the presence of acetone and a trace of albumin. Blood cultures were repeatedly positive for the hemolytic *Staphylococcus aureus*. Roentgeno-

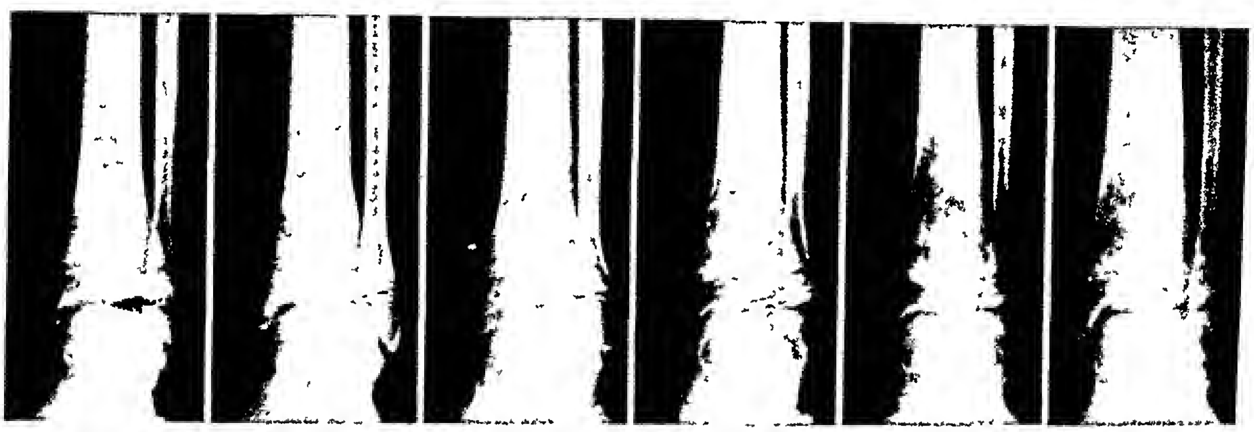

Fig. 2. Showing bony changes occurring in Case 4. 10-26-43. Small area of rarefaction on the outer aspect of tibia, just above the ankle, with a very tiny break in the cortex. No periosteal reaction on medial aspect, lower third. 11-17-43. Mottling of lower one-fourth of tibia due to irregular areas of rarefaction. Very slight periosteal reaction on medial aspect, lower third. 1-4-44. Mottling has increased in lower portion of tibia and periosteal reaction is now very well defined. Also slight periosteal elevation on outer aspect of fibula, distal one-fourth. 3-31-44. More extensive bone rarefaction and periosteal reaction than on previous roentgenograms. Several breaks in tibial cortex now easily seen. 6-2-44. Less mottling than previously and almost complete disappearance of the periosteal reaction. No sequestration anywhere. 12-22-44. All mottling has disappeared and no periosteal reaction remains. Healing of the infection appears complete.

grams showed a small area of rarefaction of the outer aspect of the tibia just above the epiphyseal line with a very small break in the adjacent cortex (Fig. 2). Changes in both upper lung fields suggested an acute embolic pneumonitis.

A diagnosis of *Staphylococcus aureus* bacteriemia with acute hematogenous osteomyelitis of the right femur and left tibia and embolic staphylococcus pneumonia was made. Penicillin was started on the first hospital day and after two doses of 25,000 units he was given 15,000 units intravenously every three hours. Three and one-half days later the dose was reduced to 10,000 units and four days later to 5,000 units. It was discontinued on the twelfth hospital day. Both legs were supported in long casts which were bivalved for purposes of observation of the involved areas. Little response to penicillin therapy was evident for seventy-two hours, the temperature remaining high, the blood cultures remaining positive and the signs of local inflammation persisting. Following this, the fever gradually fell and reached 99° F. on the twelfth day after the start of penicillin therapy where it remained until the twenty-seventh hospital day.

On November 17, 1944, the roentgenograms showed periosteal elevation along the medial aspect of the distal end of the right femur and the lower third of the left tibia with mottling of the lower metaphysis of the tibia (Fig. 2).

He was discharged from the hospital on November 24, 1943, his thirtieth hospital day with no clinical evidence of active infection.

On January 4, 1944, the periosteal reaction was more marked on the tibia and evident over the outer aspect of lower end of the fibula. The mottling in the lower portion of the tibia had increased in extent and degree.

The casts were removed the first week in March and he was allowed to resume activity gradually. On March 31, 1944, there was more extensive rarefaction and periosteal reaction of the lower ends of the tibia and fibula than on the previous roentgenograms. Several breaks in the tibial cortex were easily seen. On June 2, 1944, partial recalcification of the areas of rarefaction and almost complete disappearance of the periosteal reaction indicated that healing was taking place. The last roentgenograms on December 22, 1944, were interpreted as showing further calcification of the previously rarefied areas with apparently complete healing. The clinical examination at that time showed no abnormality or evidence of active infection.

Case 3. J. C., white male infant, aged thirteen months, was admitted to Children's Hospital on October 23, 1943, with a history of fever associated with redness, swelling, and marked pain of the entire left lower leg of more than three days' duration. He had been given sulfathiazole without obvious clinical improvement during the three days prior to admission.

At the time of admission there were marked edema, redness and tenderness over the external malleolus, shaft of the fibula, and lower end of the tibia. The temperature was 102° F. and the white blood count was 32,000 cells per cubic millimeter. Urinalysis was essentially negative except for the presence of acetone. Blood cultures were negative. Roentgenograms showed no evidence of osteomyelitis. A clinical diagnosis of acute hematogenous osteomyelitis of the fibula was made. He was treated conservatively by immobilization of the extremity and administration of penicillin giving 15,000 units and later 10,000 units every three hours intravenously and intramuscularly. No surgical drainage was carried out.

Eight days after the onset of symptoms the cast was bivalved and a small subperiosteal abscess was aspirated yielding 12 cc. of thick gray pus containing staphylococci. The cast was reapplied and the patient continued to receive penicillin and general supportive therapy. On the fifth day after the start of penicillin therapy, the temperature began to fall, reaching normal six days later. The patient was discharged to his home with no external signs of active inflammation present in the leg. No draining sinuses or residual edema were apparent. Progress roentgenograms taken at intervals during the eleven months after onset of disease are shown in Figure 3.

On November 25, 1945, one month after admission to the hospital and approximately two weeks after completion of the penicillin therapy, considerable involvement of the proximal and distal ends of the fibula had developed with periosteal reaction involving most of the shaft and sequestration of practically two-thirds of the fibular shaft. Approximately three months after admission, on January 18, 1944, the periosteal reaction was increased in amount and was forming a new bony shaft for the fibula. The sequestrum of the old shaft of the fibula had been partially and spontaneously absorbed.

After this, the child moved to another state and contact was maintained through his

orthopedic surgeon. Shortly after moving, he developed two small draining sinuses in the lower part of the affected leg and the roentgenograms on April 29, 1944, showed that the long narrow sequestrum was detached and was working its way to the surface. During a subsequent change in plaster casts, the sequestrum was found to be partially extruded from one of the sinuses and was therefore removed. Approximately eleven months after onset of the disease, the roentgenograms showed reconstruction of the entire fibula with was usually of limited extent and in some cases the sequestrum acted as an autogenous bone graft, becoming revascularized and viable to participate in the reconstruction of the involved bone (Fig. 4).

The local infection was arrested with more difficulty in this type of case and longer periods of treatment with penicillin were usually required. Small abscesses were treated by aspiration and large ones by incision and drainage.

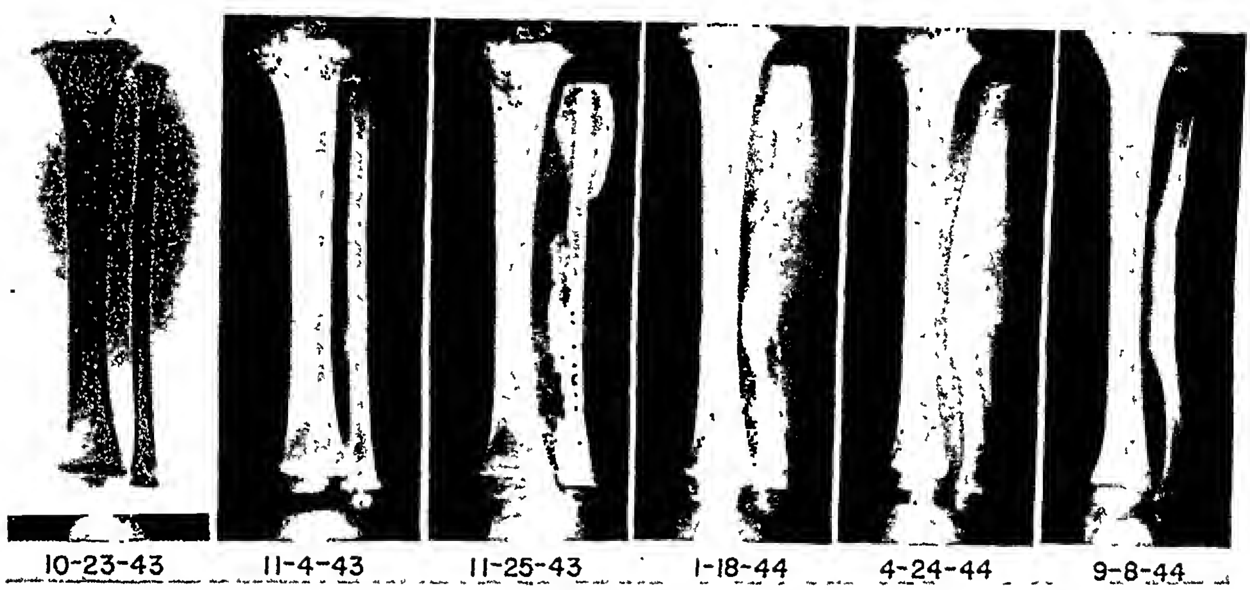

Fig. 3. Showing the bony changes occurring in Case 3. 10-23-43. No definite roentgen findings in bone or periosteum. 11-4-43. Rarefaction at proximal and distal ends of fibula with associated periosteal reaction. Also an area of periosteal reaction at level of junction of middle and lower thirds. 11-25-43. Bone destruction involving lower two-thirds of fibula. Absorption of proximal end. Marked periosteal reaction in these areas. Practically two-thirds of shaft is sequestrating. 1-18-44. Reconstruction has taken place in major portion of the fibula. The sequestrum is absorbing. Slight increase in the degree of periosteal reaction at proximal end. 4-24-44. Almost entire shaft has become recanalized. Long narrow sequestrum remains on outer portion of fibula in its middle third. 9-8-44. Entire fibula has been reconstructed. Remainder of sequestrum not absorbed has been removed.

apparently complete healing. There has been no disturbance of growth of this leg, no deformity, and no impairments of function of adjacent joints. In October, 1944, the child was reported to be running about normally without complaints or signs of infection.

Group III. When the diagnosis and treatment were delayed for seven to ten or more days, or when the infection was unusually severe, local destruction of bone became very great and soft tissue abscess formation and sequestration occurred in most but not all of the cases. Sequestration, however,

The bony changes as revealed by roentgenograms showed extensive bone destruction at the start of penicillin treatment, which increased on subsequent examinations. Sequestration occurred in some instances. Smaller sequestra have been absorbed spontaneously and larger ones apparently have acted as autogenous grafts. In Case 3 the sequestrum was spontaneously and partially discharged while in Case 22, the large sequestrum is undisturbed, apparently viable and taking part in reconstruction of the shaft of the radius.

CASE 21. R. S., white male, aged eight, was admitted on the pediatric service of the Cincinnati General Hospital on March 27, 1944, complaining of fever and a painful swelling in the left shoulder and elbow of four days' duration. Several days previously he had had a tonsillectomy.

On examination his temperature was 103° F., pulse 120, and respirations 26. The sclerae were icteric. There was a loud systolic murmur audible over the apex of the precordium. Extending from the left shoulder to the elbow was a hot, reddened, edematous area which was exquisitely tender. Limitation of motion of both elbow and shoulder joints was present.

The white blood count was 18,700 cells per cubic millimeter with 80 per cent polymorphonuclear leukocytes. The urinalysis was negative. The icteric index was 13 and cephalin flocculation test was 4+ in twenty-four hours. The van den Bergh test showed a moderately positive prompt biphasic reaction. Blood cultures taken then and subsequently were reported as negative and chest roentgenograms were essentially normal.

A diagnosis of rheumatic fever was made and treatment with antipyretics was started. Sulfadiazine therapy was started on March 31, 1944, the fourth day after admission, giving 1 gram every four hours without noticeable clinical improvement. On March 31 the roentgenologist described periosteal reaction about the upper two-thirds of the shaft of the humerus with some demineralization of the underlying bone (Fig. 4). Repeated roentgen examinations showed gradual increase in these changes which were quite extensive on the thirteenth hospital day. Pus was aspirated from a soft tissue abscess over the upper lateral aspect of the arm and the hemolytic streptococcus was cultured from it. At this time we were asked to see the patient, and it was elected to treat the osteomyelitic process with penicillin, giving 10,000 units every three hours intramuscularly. The soft tissue abscess was again aspirated and 15,000 units of penicillin in 3 cc. of saline

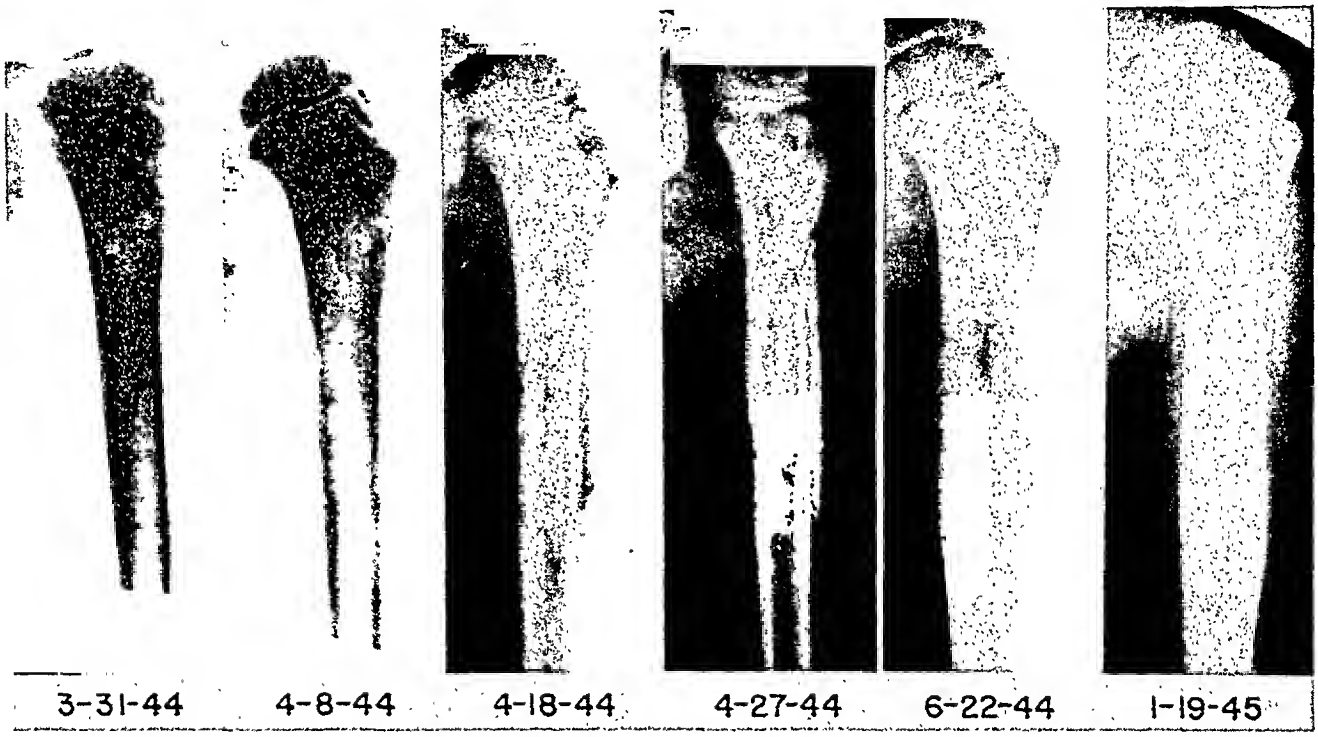

FIG. 4. Illustrating the bony changes occurring in Case 21. 3-31-44. Mottling at upper end of shaft of humerus and very slight periosteal reaction on outer aspect of upper one-fourth of shaft. 4-8-44. Mottling has continued down the shaft to junction of upper and middle thirds. Periosteal reaction present both sides of shaft. 4-18-44. Marked increase in periosteal reaction. Very small sequestrum seen under periosteum on outer aspect. 4-27-44. Osteomyelitis has increased considerably and a long narrow sequestrum is present on lateral aspect of shaft. Periosteal reaction has increased, particularly over the sequestrum. 6-22-44. Reconstruction of the shaft has taken place. The sequestrum has been involved in the process of recalcification and healing. 1-19-45. Complete healing and reconstruction.

solution were instilled into the abscess cavity. Within seventy-two hours after the penicillin was started, the temperature fell to 99.2° F., and thereafter this elevation was never exceeded. The subperiosteal abscess was aspirated on two occasions followed by instillation of penicillin. No organism was cultured from the aspirated material after eight days of penicillin therapy. The dose was reduced to 5,000 units every three hours after the eleventh day of penicillin treatment and discontinued two days later.

Serial roentgenograms of the involved humerus revealed striking bony changes (Fig. 4). On April 8, 1944, at the start of penicillin therapy, extensive destruction of the bone produced by the infection of thirteen days' duration was evident. Near the completion of penicillin therapy, the roentgenograms showed a marked increase in the extent of periosteal reaction and the formation of a small sequestrum. On April 27, 1944, one month after his admission to the hospital, the rarefaction of the humeral shaft and periosteal reaction had reached its maximum and a long narrow sequestrum was present on the lateral aspect of the shaft. Two months later (June 22, 1944) marked recalcification and reconstruction of the involved bone had occurred spontaneously, the sequestrum apparently participating in the healing process (Fig. 4).

He was transferred to the Children's Convalescent Home on his forty-seventh hospital day and an early return to normal activity was possible under supervision. After a stay of three months at the institution he returned home entirely without symptoms. Progress roentgenograms on January 19, 1945, showed apparently complete healing.

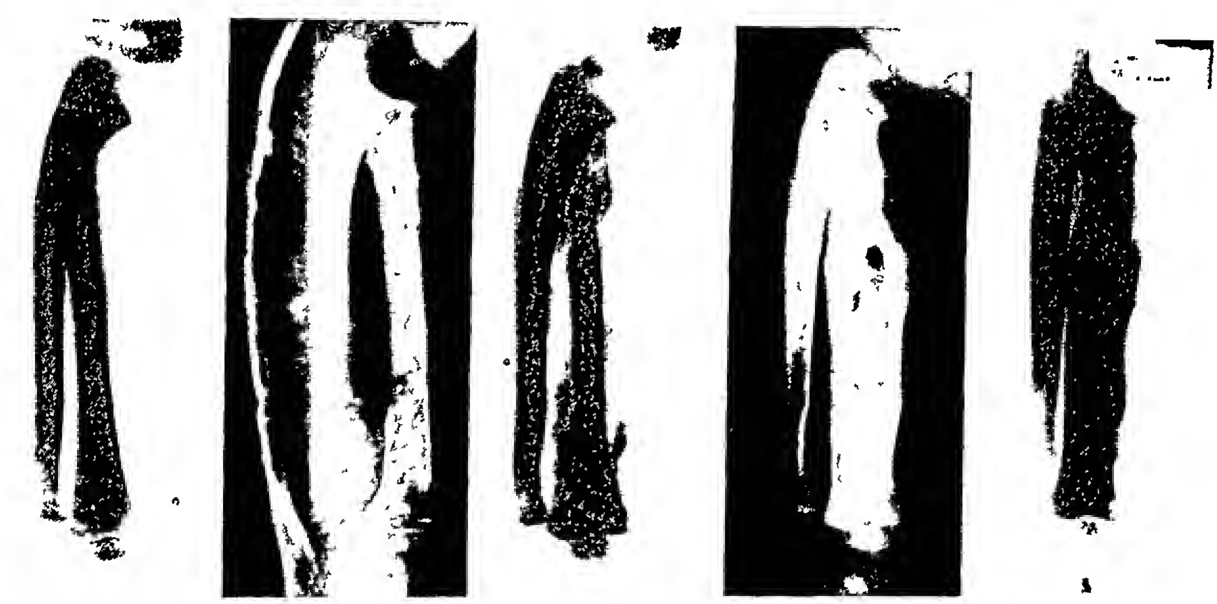

FIG. 5. Showing bony changes occurring in Case 22. 6-20-44. Rarefaction at distal end of radius, most likely early osteomyelitis. 6-29-44. Rarefaction has extended upward through distal half of radius and also involves the proximal one-fourth. Several breaks in the cortex. Periosteal reaction present, especially proximal end. 7-15-44. Very extensive periosteal reaction with absorption of both ends of the shaft and beginning sequestration of the middle third. 10-27-44. Extensive healing and reconstruction of the radius. The sequestrum representing the middle third of the radial shaft apparently has become revitalized. 2-6-45. Practically complete reconstruction of the radius.

CASE 22. R. J., Negro male, aged three, was admitted to the Cincinnati General Hospital on June 14, 1944, with a chief complaint of swelling throughout the right forearm. Two days earlier he had cut his right palm and at that time it was noted that he also had a furuncle of his scalp.

He appeared acutely ill and his temperature was 104.6° F. There was a healing laceration of the left thenar eminence. Extending from the left wrist to the shoulder was a warm, exquisitely tender swelling which was greatest throughout the forearm.

The white blood count was 21,000 cells per cubic millimeter and the urinalysis showed the presence of acetone. Blood cultures were reported as negative on admission as well as on repeated subsequent examinations. Roentgenograms on his sixth hospital day showed small areas of demineralization and periosteal reaction about the distal end of the radius, but these were overlooked.

A diagnosis of acute cellulitis of the forearm secondary to an infected laceration of the hand was made. Sulfadiazine was started, $7\frac{1}{2}$ grains being given every four hours. Massive wet compresses were applied to the arm. After twenty days on sulfadiazine therapy he continued to have daily elevations of temperature to approximately 100° F. and the appearance of the arm did not change appreciably. The bone changes as revealed by the roentgenogram had progressed markedly. Rarefaction of the distal half and proximal fourth of the radius with periosteal reaction was obvious, and several breaks in the cortex became visible, making the diagnosis of acute osteomyelitis of the radius apparent.

On the twenty-third hospital day, we were asked to see the patient and pencillin therapy was started, giving 10,000 units intramuscularly every three hours. Sulfadiazine was discontinued. The arm was immobilized in a long arm cast. After five days the dose was reduced to 5,000 units every three hours. The course was one of slow improvement. The roentgenogram taken on July 15, 1944, showed more extensive periosteal reaction with absorption of both ends of the radial shaft and beginning sequestration (Fig. 5). On July 20, 1944, after fourteen days of penicillin therapy, aspiration of the forearm yielded a few cubic centimeters of fluid from which hemolytic *Staphlococcus aureus*, *Staphylococcus albus*, and a streptococcus were cultured. He was discharged on his fifty-sixth hospital day greatly improved. When seen in the clinic on August 28, 1944, there was still some swelling of the forearm with a palpable irregularity along the surface of the radius. Progress roentgenograms taken on October 27, 1944, 137 days after the onset of illness, showed that the periosteal reaction had thrown up an enveloping bridge of new bone about the sequestrum representing the old radial shaft. Of particular note is the apparent revitalization of the sequestrum similar to that seen in autogenous bone grafts. On February 6, 1945, 239 days after the onset of the disease, marked healing had occurred with recalcification and spontaneous reconstruction of the radius. The sequestrum had participated in this process.

Group IV. In certain fulminating infections in which it is apparent that the patient will not live the forty-eight or more hours necessary to obtain the maximum effect of penicillin, surgical intervention after adequate preoperative preparation is still necessary as an emergency measure. Penicillin was administered preoperatively and postoperatively in doses of at least 15,000 units every one to three hours. In such instances, the bone destruction was extensive due to the severity of the infection.

Case 29. G. C. white male, aged two, was admitted to the Children's Hospital on July 6, 1944, complaining of pain and swelling of the left foot and lower leg of three days' duration. Wet dressings had been applied and an unknown type of sulfonamide administered the day before admission. During the preceding two weeks he had an acute upper respiratory infection and ten weeks before he had had epidemic meningitis from which he had made a complete recovery.

Examination showed an acutely ill and profoundly toxic white boy whose temperature was 104.2° F. There was a profuse nasal discharge. The left foot was red, hot, tender, and swollen to a level about the ankle. A large vesicle containing blood-stained fluid was present over the area of greatest swelling.

The white blood count was 15,250 cells with 86 per cent polymorphonuclear leukocytes and the red blood count was 3,960,000. Urinalysis showed the presence of albumin and an occasional red blood cell. All blood cultures taken were negative. Roentgenograms on July 7, 1944, showed swelling in the soft tissues, but unfortunately they showed only a small portion of the lower leg (Fig. 6).

Aspiration of the fluid in the large hemorrhagic vesicle was performed and examination of a stained smear of this material showed the presence of numerous small chained gram-positive cocci. These were interpreted as streptococci and a tentative diagnosis of hemolytic streptococcic gangrene was made.

Sulfadiazine gr. v and an equal amount of bicarbonate of soda were given every four hours. Penicillin was started on the second hospital day, 10,000 units being given intramuscularly every three hours to an infant of two years of age.

The patient's condition became rapidly worse during the ensuing twenty-four hours, and it became evident that he would die before the passing of an additional twenty-four hours. At this time it was learned that the culture of the fluid aspirated from the vesicle showed that the gram-positive coccus was a hemolytic *Staphylococcus aureus*, and not a hemolytic streptococcus. A diagnosis of acute hematogenous osteomyelitis was made and immediate operative intervention was decided upon. On the way to and in the operating room the child had two series of generalized convulsions. Under drop ether anesthesia two long incisions were made rapidly through the skin and subcutaneous tissues of the lateral and medial aspects of the leg and foot. A necrotizing purulent infection was found in the subcutaneous tissues over the entire leg and dorsum of the foot. On the lower lateral aspect of the leg an area of slough with perforation was found in the fascia. The wound was loosely packed with gauze incorporating four Dakin's tubes and the patient was returned to his room in very poor condition. He received continuous oxygen therapy, intravenous injection of 5 per cent glucose in saline solution, and several transfusions of 250 cc. of fresh whole blood. Treatment with penicillin was continued giving 15,000 units every three hours for the next eighteen days and 10,000 units at the same interval for an additional eight days.

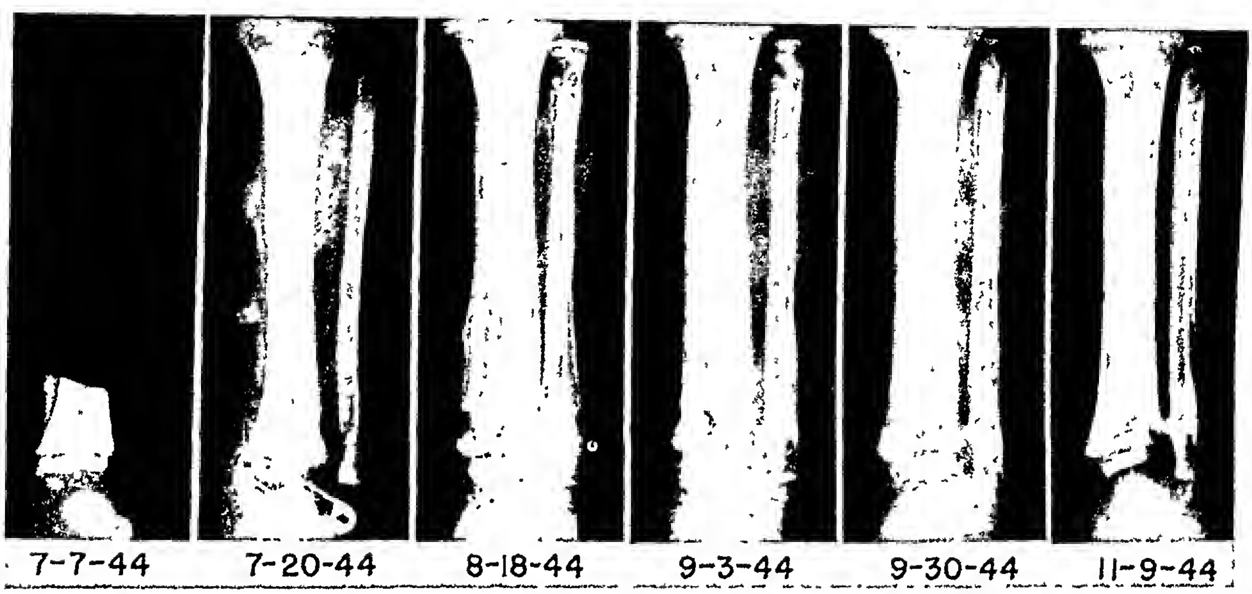

Fig. 6. Illustrating bony changes occurring in Case 29. 7-7-44. No evidence of bone or periosteal involvement. 7-20-44. Area of bone destruction at both ends of fibula and an area of rarefaction with break in cortex on medial aspect of distal end of tibia. Periosteal elevation on lateral aspect of tibia, distal half. 8-18-44. Extensive destruction both ends of fibula and lower half of tibia. Periosteal reaction has developed along the full length of both shafts. 9-3-44. Progress of the infection has been halted and healing has begun, both in the bone tissue and the periosteum. 9-30-44. Both ends of fibula and lower end of tibia have become recanalized. The tibial periosteal reaction of the periosteum of the fibula is about the same. 11-9-44. Reconstruction of upper end of fibula is complete. Deformity at lower ends of fibula and tibia has persisted but the infection has apparently completely subsided. Tibial periosteum has returned to normal except for a small area on medial aspect of shaft. Periosteum of fibula remains thickened.

Striking improvement occurred in his general condition, becoming evident within the first twenty-four hours after operation and continuing during the following seven days. The sloughing tissues in the wound were replaced by red healthy granulation tissue and the wound gradually and spontaneously healed with the exception of a small area 2 cm. in diamater over the lower lateral aspect of the leg.

Roentgenograms taken on July 20, 1944, twelve days after onset of penicillin therapy

and ten days after operation, showed destruction and periosteal reaction at the distal ends of the tibia and fibula and involvement of the tibio-astragalar joint. A long leg cast was applied on the twenty-first day after operation and he was discharged on the forty-seventh day. He was afebrile at this time and his general condition was very good. On August 18, 1944, forty-one days after start of penicillin, and after its completion, the appearance of the roentgenograms was much worse than it was at any time before or during the administration of penicillin. Extensive demineralization and rarefaction of both ends of the fibula and lower half of the tibia with marked periosteal reaction along the full length of both shafts had developed. Fifty-seven days after the start of penicillin, early healing had become manifest by fusion of the periosteal new bone with the cortex and beginning recalcification of the rarefied areas. There was no evidence of sequestration. On November 9, 1944, 129 days after the onset of the illness, marked healing had occurred with complete reconstruction of the upper end of the fibula and tibia, and partial recalcification and reconstruction of the lower end of the tibia and fibula. In October, 1944, the patient began active weight bearing after removal of the cast. On November 23, 1944, the wound had completely healed and the patient was without complaint.

DISCUSSION

The roentgenographic changes in bone occurring in acute hematogenous osteomyelitis treated with penicillin are of particular interest. Early in the disease, during the first four to ten or more days, the roentgenograms are of no practical value in detecting the nature of the disease. This emphasizes the fact that the diagnosis of acute osteomyelitis is purely a clinical one at the time when early and adequate treatment with penicillin will minimize or prevent damage of bone. In many instances, penicillin therapy had sterilized the blood stream and had brought the generalized and localized manifestations of infection under control before any evidence of bone damage became obvious.

Later in the disease, usually after the cessation of chemotherapy, a succession of roentgenographic changes occurred. These changes varied with the age of the patient, the severity of infection, the duration of infection before treatment with penicillin, the adequacy of therapy, and the type of infecting bacteria. Periosteal reaction, patchy areas of demineralization and rarefaction of the involved bone, and breaks in the adjacent cortex were early signs which usually became evident ten to fourteen days after the onset of the illness. These findings increased in extent and degree, and were invariably interpreted by the roentgenologist as representative of "an extension of the osteomyelitic process." We have learned to interpret the areas of rarefaction and breaks in the cortex of the involved bone as a measure of spontaneous absorption of the bone destroyed early in the course of the infection rather than a measure of an extension of the osteomyelitic process. The process suggests that adequate penicillin therapy given early arrests and controls the infection, converting an area of septic necrosis of bone to one of aseptic necrosis.

The spontaneous absorption of the dead bone is followed by recalcification of the involved area often with re-establishment of normal or near normal bony architecture. Reconstitution of the bone was accomplished with less resultant bone sclerosis than that seen by other previous forms of treatment.

We suspect that a process similar to that seen following the transplantation of autogenous bone grafts occurs in acute osteomyelitis treated adequately with penicillin. It has been known for a long time that aseptic absorption of dead bone occurs in transplanted bone grafts.[2] When bone is transplanted to another location, a considerable part of it dies, but those bone cells which are still bathed in lymph and body fluids continue to live and show marked proliferation in the course of a few days. Revascularization of the necrosed bone is accomplished by new vessels growing from the surrounding tissues into the haversian canals. Proliferating osteoblasts accompany the new vessels, giant cells appear and the

dead bone undergoes absorption and conversion into a series of spaces lined by osteoblasts. The formation of new bone is then accomplished by these cells. In this manner the graft becomes partially absorbed and then replaced.

Although sequestration was relatively uncommon in cases treated with penicillin, it still occurred late in the illness if the infection was unusually severe, the diagnosis was delayed or the treatment inadequate. When it did occur, it was usually followed by spontaneous absorption of the smaller pieces, partial absorption of the larger ones, spontaneous extrusion of detached larger sequestra, or by recanalization and organization of large sequestra similar to autogenous bone grafts. Sequestrectomy may be necessary in 2 cases later.

In the past we have been impressed with the degree of secondary infection in areas of osteomyelitis treated by surgical drainage. Devitalized tissue exposed to the air invites mixed or saprophytic infection, particularly by various gram-negative bacilli, and it is often difficult to prevent this type of infection. Such secondary invaders have frequently been penicillin resistant or even penicillin destructive. The elimination of this complication by penicillin therapy may be a very important factor in the arrest of the local infective process and the spontaneous absorption of devitalized bone.

SUMMARY AND CONCLUSIONS

Penicillin is a powerful chemotherapeutic agent which has reduced the mortality and morbidity in acute hematogenous osteomyelitis by effectively bringing the infection under control and by decreasing the local destruction of bone and resultant deformities. A study of cases treated with penicillin has radically altered our interpretation of the roentgenographic changes developing in this disease. Although the roentgenogram is of little or no value in making an early diagnosis of acute hematogenous osteomyelitis, it is of definite value in the recognition of the process after ten to fifteen days beyond the onset. A succession of changes occurring in bone have been described in the cases treated adequately with penicillin which have been interpreted as a measure of the process of spontaneous repair and not as an indication of further extension of the osteomyelitic process as has been generally assumed. The spontaneous removal of necrosed bone has been followed by recalcification and healing of the involved areas.

REFERENCES

1. Altemeier, W. A., and Helmsworth, J. A. Penicillin therapy in acute osteomyelitis. *Surg., Gynec. & Obst.*, August, 1945, *81*, 138–157.
2. Boyd, W. Surgical Pathology. W. B. Saunders Co., Philadelphia, 1942, pp. 668–669.

Vol. 54, No. 5

STUDIES ON ROENTGEN DEATH IN MICE*

I. SURVIVAL TIME AND DOSAGE

By HENRY QUASTLER, M.D.

URBANA, ILLINOIS

INTRODUCTION

THE series of investigations of which this is the first report deals with reactions of mice to lethal doses of roentgen rays. The emphasis will be on reactions which can be measured, on their quantitative relations to the doses administered, and on the evaluation of factors which influence the dose-response relation. The present paper deals with the speed of the processes leading to death expressed by the survival time elapsing between irradiation and death. The dosage range investigated extends from 500 to 25,000 roentgens. It will be shown that it is divided into four zones, each with distinctive characteristics of the dose-response relation.

MATERIAL

Inbred mice were used in these experiments. They were from five to twenty-five weeks old and weighed 20 gm. ±15 per cent, i.e., from 17.4 to 23.0 gm. They were kept in wooden bins, 2 to 20 mice in a bin, and had unlimited access to water and food ("Purina" dog chow).

Our standard strain† is C57-Black. These mice are derived from a Bar Harbor strain, and have been continued in Illinois since 1938 by successive brother-to-sister matings. Some of the mice represented in this report come from two other strains of about equal roentgen sensitivity, called strains L and B. Strain L is derived from the Swiss stock, and has been inbred systematically in Illinois since 1939. Strain B is an anophthalmic strain, inbred since 1938 in Bar Harbor, and later in Illinois, and described in a series of papers by H. B. Chase and E. B. Chase.[1] In addition, a few first generation hybrids between the above strains were used.

† A strain is obtained by continued and uninterrupted brother-to-sister matings in successive generations. Mice belonging to one strain are the closest approach to genetically homogeneous mice which can be obtained. A stock is obtained by continuous inbreeding within the progeny of one couple, without regard to the relationship between mates. A stock is less pure than a strain.

METHOD OF IRRADIATION

The definition of the roentgen dose administered to a mouse involves certain difficulties. The biologic effect depends on the tissue, or effective, dose. This dose consists of two components, the primary radiation delivered, and the secondary radiation arising within the irradiated subject. The amount of the latter depends on the size and shape of the object. It is small if the beam of rays hits only a single mouse, becomes considerable when several mice are irradiated together in a box, and reaches up to 50 per cent of the primary radiation if the mice are subjected to backscatter from the support. Thus, the effective intensity can deviate considerably from the primary intensity.

In general it is desirable to know the absolute value of the effective dose. This can be accomplished in two ways: either by irradiating the mice singly, suspended free in air with a minimum of support, in which case the tissue dose is practically equal to the amount of primary radiation delivered; or, by arranging the mice in a way that the amount of secondary radiation they receive is measurable and reproducible. The latter way is the one we selected.

A phantom was designed to permit irradiation with doses which are reproducible, measurable, and nearly homogeneous throughout the body of the animals. It was built of sheets of pressdwood, sp. gr. 1.1, measuring 16 by 16 by $\frac{1}{4}$ inches. In the center of six sheets, rectangles of 2 by 3 inches were cut out; these sheets were bolted together with a seventh one which formed the bottom. A sheet placed on top of this block formed the ceiling of a chamber

* From the Department of Radiology, Carle Hospital Clinic, Urbana, Illinois.

measuring 3 by 2 by $1\frac{1}{2}$ inches, situated in the center. The whole block was placed on fifteen additional sheets of pressdwood providing the backscatter. The central beam was directed through the center of the block. Two to 4 mice were irradiated at a time. They filled about half the space in the chamber. The remaining, irregularly shaped air space proved to be sufficient to prevent anoxemia and is not believed to change substantially the dose distribution.

It can be seen that the postulate of homogeneous dosage distribution was reasonably well fulfilled. The variety of settings used is due partly to changes in the apparatus (the experiments were carried out during a period of two years), partly to special investigations which yielded negative results, i.e., the differences between the settings described did not appreciably influence the effects obtained. Setting G involved the use of a special phantom designed for high intensity with little regard for dose distribution. This phantom consists of a cylinder of pressdwood which contains a cylindrical chamber of 5 cm. diameter and 2 cm. depth. It was used only for the highest doses.

Table I

SETS OF IRRADIATION CONDITIONS USED

Setting	kv.* max.	Filter	Half-Value Layer in mm. Cu	ma.*	Distance Target-Center of Chamber in cm.	Effective† r/min.	Highest** r/min. in Per Cent of Effective r/min.	Lowest‡ r/min. in Per Cent of Effective r/min.
A	183	0.75 mm. Cu +1 mm. Al	1.20	6.25	52.5	15.4	102	97
B	200	0.75 mm. Cu +1 mm. Al	1.34	10.0	92.0	9.5	102	97
C	200	0.75 mm. Cu +1 mm. Al	1.34	10.0	48.75	18.8	102	97
D	200	0.75 mm. Cu +1 mm. Al	1.34	10.0	37.5	33.6	103	96
E	200	0.5 mm. Cu +1 mm. Al	1.10	8.0	37.5	37.6	104	94
F	200	None	0.34	8.0	37.5	117.0	106	93
G	200	None	0.34	8.0	27.0	220.0	—	—

* As read on the instruments on the control panel.
† Intensity at a point 1.5 cm. above the floor of the chamber and 2.5 cm. off center.
** Intensity at a point 0.5 cm. below the ceiling, in the center beam—considered the highest intensity likely to hit any sensitive part of the mouse.
‡ Intensity at a point 0.5 cm. in each direction from a lower corner of the chamber—considered the lowest intensity likely to hit any sensitive part of the mouse.

For the determination of depth dose distributions, the block of sheets with the chamber was replaced by another set of sheets containing a tunnel into which the thimble of a Victoreen condenser r-meter was introduced.

Figure 1 shows the mouse chamber and dosage distribution charts for two different sets of conditions (settings) used, one considered satisfactory, the other showing poorer homogeneity of dosage.

Table 1 contains the data for all of the settings used in the experiments here reported.

GENERAL OBSERVATIONS

Several descriptions of the clinical and pathological picture of roentgen death in mice and other mammals have been given lately.[2,4,5,6,7,8,10] We can therefore restrict this chapter to a brief survey.

(1) *The Hyperacute Reaction.* A hyperacute reaction is produced by doses of 8,000 r and more, in our standard mice (C57-Black of about 20 gm. weight). The clinical picture is dominated by convulsions which appear immediately after doses of 15,000 r and more, after a latency period of a few hours with doses of 8,000 r. The symptoms are light and transitory with doses up to 12,000 r. With higher doses, the convulsions become increasingly severe, and death occurs during an attack at from three days down to minutes after the irradiation.[6]

(2) *The Acute Reaction.* Acute roentgen death is produced in about three and one-third days by doses from 1,175 to 12,000 r. The earliest symptom we observed is weight loss, which can be found, in the majority of cases, almost immediately after the irradiation. The weight decreases steadily ,and reaches about two-thirds of its original value at the time of death. On the second to third day, anorexia and diarrhea,[8] pallor, and flurriness of the fur become manifest. On the third day, the animals become weak, move little and slowly, and show a characteristic arching of the back. An hour or so before death, the respiration begins to slow down, and death occurs usually with terminal convulsions.

Pathological examination reveals a multiplicity of marked changes in many vital organs such as liver, spleen, lungs, kidneys, and intestines. In some cases, every one of these organs seems to be damaged severely enough to account by itself for the death of the animal.[10]

Doses of 600 to 1,200 r produce always, doses from 300 to 600 r sometimes, the picture of acute roentgen death, with the only difference that the course is slower and the interval between irradiation and death lengthened up to two weeks.

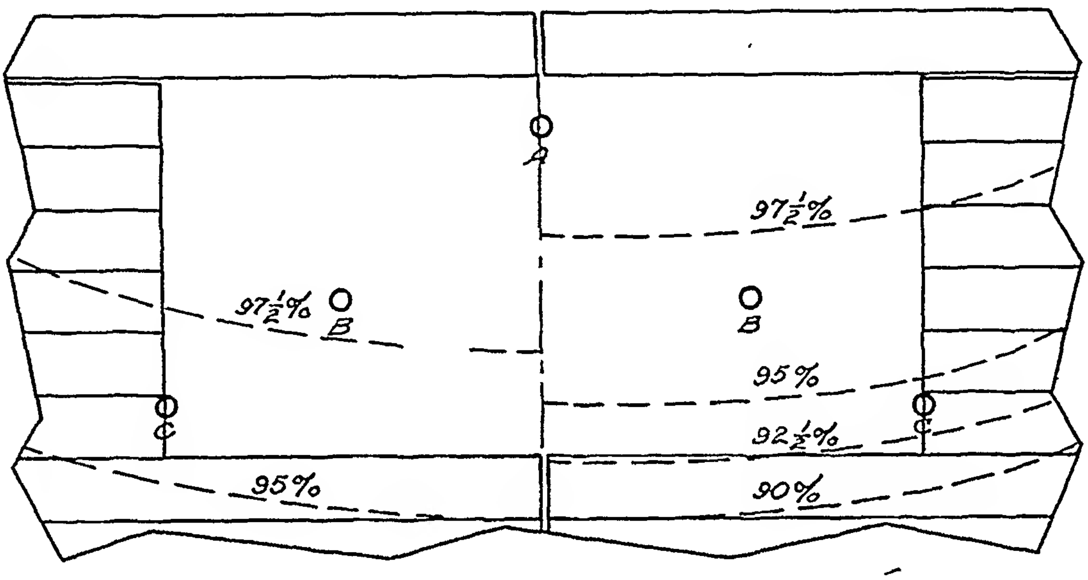

Fig. 1. Section through the mouse chamber of the phantom, with isodose lines for two settings. The effective intensity is measured at point *B*, the highest at *A*, the lowest at *C*.

(3) *The Subacute Reaction.* In the dosage range from 200 to 600 r, the weight, which first decreases, is sometimes arrested at a constant level for periods of days, or starts increasing again. This intermediate stage is sometimes followed by a second phase of more or less rapid weight loss accompanied by symptoms similar to those of the acute phase, and leading to death in one to six weeks after the irradiation.

The pathological picture is different from that observed in acute roentgen death. The spleen is often enlarged and shows intense regeneration of white cells. The liver is often enlarged, sometimes fatty. In some cases it shows zones of necrosis alternating with zones of healthy regenerating cells. Changes in the lungs are sometimes localized to a single lobe.

(4) *Survivors.* Animals surviving doses of 200 r and more, are sterile, grow less than their litter mates, and have a grizzly coat. Otherwise, they appear healthy. On pathological examination, the organs appear normal except for occasional fibrosis.

SURVIVAL TIME

The survival time is the time elapsed between irradiation and death. Our records of survival time and doses for 101 mice of about 20 gm. weight, which died within forty days after irradiation, are assembled in Figure 2. Each symbol represents an individual mouse, its position indicating the survival time (between irradiation and death) and the dose.

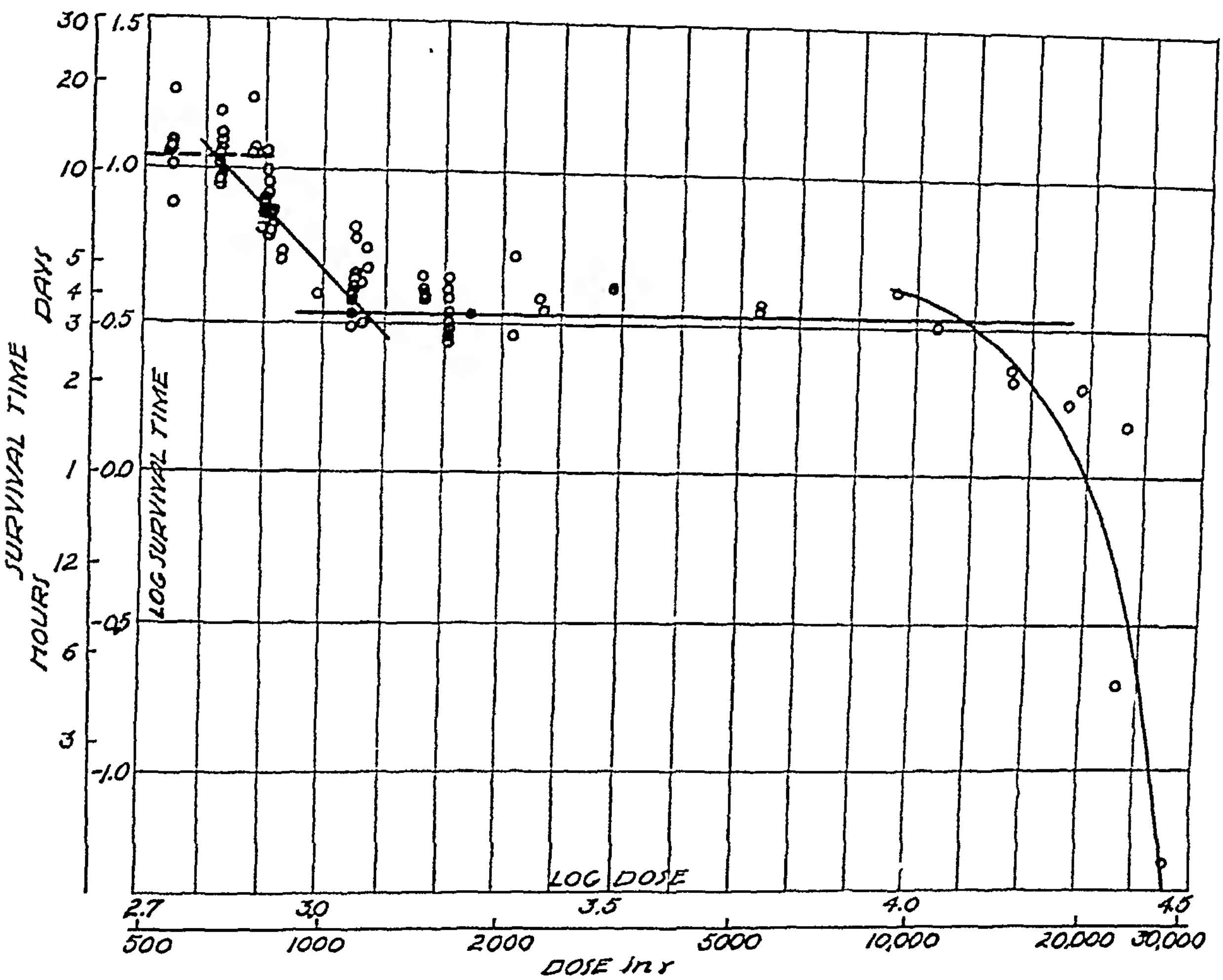

Fig. 2. Survival time of mice after whole body irradiation. Abscissa—dose in roentgens; ordinate—survival time in hours and days; circles—individual observations.

A certain margin of error is conceded for both the values of dose administered, and survival time. The dose estimate might differ from the actual dose delivered by up to 3 per cent because of fluctuations in the output of the machine. Another 3 per cent might be added for effects of position of the mice within the irradiation chamber. In addition, there is the possibility of gross errors in timing the irradiations. The survival time could be determined precisely in a few cases where the dying was actually observed. Most mice died at times when checks were being made at frequent intervals, so that in these cases the survival times are accurate within one-tenth of a day at the most. About one-fourth of the mice died at times when checks were being made at irregular intervals ranging up to twenty hours, and in these cases our estimate (based on the degree of postmortem changes present) may be off by up to one-fourth of a day.

The survival times of mice which have received a given dose show some variation, with

the longest intervals between irradiation and death about twice as long as the shortest intervals observed with the same dose. Some of this dispersion can be accounted for by experimental inaccuracies, but most is due to true variability. Hence, it is necessary to use statistics in order to obtain a simple expression of the dose-survival time relation. As a single value representing the class of survival times obtained with a given dose, we have selected the "logarithmic mean survival time," which is nearly identical with the "median survival time" (m.s.t.), i.e., the time after which 50 per cent of all observed fatalities have occurred. With doses which kill all the mice irradiated, the median survival time is identical with the time after which one-half of all the animals in the set have succumbed; but if, say, only 60 per cent die, the median survival time is the time after which 50 per cent of these 60 per cent, or 30 per cent of the total lot, are dead; and if only 6 out of 100 mice in a given set die, the median survival time lies between the occurrence of the third and the fourth fatality.

The trend of the median survival time, as estimated from the observations accumulated thus far, is represented by heavy lines in Figure 2. Full lines indicate the regions where we have enough material to feel that the present estimates will not be subjected to substantial corrections by further observations; dashed lines indicate a zone where the scarcity of experiments does not allow more than a preliminary estimate of the trend.

An inspection of the graph (Fig. 2) reveals that there are at least four different segments characterized by the form of the dose-response relation. The first segment, at the extreme left, seems to be a plateau, which represents survival times in subacute reactions. The few deaths observed in this low dosage range occurred after survival times of around eleven and one-fourth days.

The second and third segments represent survival times in acute reactions. The second segment extends over a dosage range from 650 to 1,175 r. It is sloping, indicating that in this zone the survival time decreases as the dosage increases. The third segment, which is the dominating feature of the whole curve, is a plateau extending over a domain of doses from 1,175 to 12,000 r. In this zone, the survival time remains at a fixed value, and changes in doses are ineffective as far as the survival time is concerned. That does not mean that changes of dosage, within this domain, will have no effect at all. For instance, motor symptoms appear at a dose of 8,000 r, and become progressively severe as the doses increase; but the survival time remains the same up to 12,000 r.

The last segment, to the right of the plateau, is the zone of the hyperacute reaction. The survival time decreases with increasing doses, first slowly, later rapidly.

It can be seen that the scattering of the symbols representing individual observations is most pronounced in the zones of transition between any two segments of the curve. It appears that in these zones of transition there may be an element of chance which determines in which of two ways an individual case may react.

In mathematical terms, the relation between dose administered (D) and median survival time (T) can be expressed as follows:

1.1 . . . $T = \text{constant} = 11\tfrac{1}{4}$ days . . . ($D < 750$ r)

1.2 . . . $T.D = \text{constant} = 4.64 \times 10^6$ . . . ($650 \text{ r} < D < 1{,}250$ r)

1.3 . . . $T = \text{constant} = 3\tfrac{1}{3}$ days . . . ($1{,}000 \text{ r} < D < 12{,}000$ r)

1.4 . . . $(\log T - 1.05) \times (\log D - 4.55) = \text{constant} = 0.25$ . . . ($D > 10{,}000$ r)

The overlapping of the ranges of the four functions indicates the "uncertainty of reaction" observed in the transitional zones. At the present stage of investigation, the formulae given are only descriptive empirical approximations and should not be interpreted as statements of the form of relation between dose and effect.

DISCUSSION

The dose-response curve here presented is new if considered as a whole, but for every single zone there are corroborative data in the literature.

Several authors have investigated dosage ranges corresponding to the first and second segment of our curve. Sugiura[9] and Ellinger[2] have presented their data in a form which allowed the estimation of the median survival time. The results of these authors are entered in Figure 3, together with the curve we obtained. It is evident that the shape of the curve is about the same for all sets of data. The subacute plateau comes upper end of this plateau was not investigated, but presumably there are doses which kill goldfish more rapidly. In studies on mammals (mice and guinea pigs) Ellinger[2] failed to establish the presence of plateaus because he did not extend his investigations to high enough doses.

The picture of the hyperacute reaction is found in the early literature and has lately been described in detail by Henshaw.[4,5,6,7]

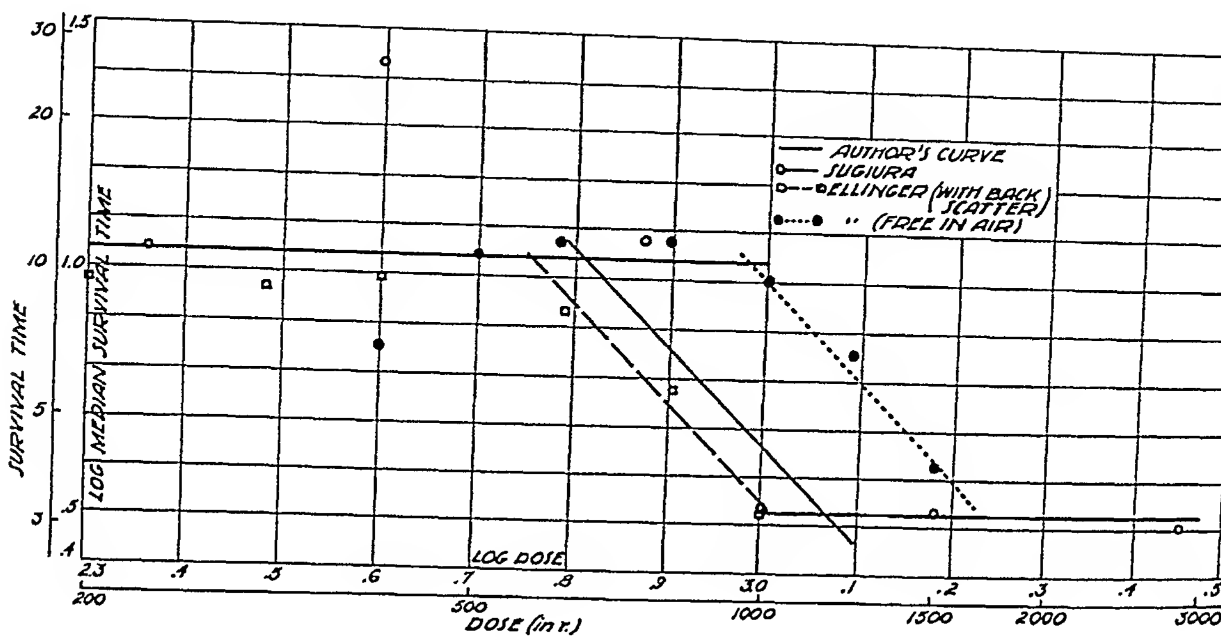

Fig. 3. Survival time and dosage. Author's curve, and data of Sugiura and Ellinger. Each symbol represents a class of mice.

out rather well in Ellinger's material. The position of the curves differs. Sugiura's data fit our curve. The two sets of Ellinger's data have been obtained with and without utilization of backscattering. From the curves, the amount of secondary radiation is estimated at 58 per cent which approximates the value of 50 per cent we would expect under the experimental conditions used.

A plateau has not been found in mice previously, but one presumably analogous to ours was established in goldfish by Ellinger.[3] Within a dosage range of from 200 to 2,000 r, increasing doses produce higher frequency and faster occurrence of deaths. At 2,000 r, the mortality is 100 per cent, and the median survival time about ten days. The reaction remains the same when the dosage is increased up to 10,000 r. The

This author had worked with small and medium doses on mice, guinea pigs, and rabbits, and proceeded to investigate whether and how far the life span after irradiation could be shortened. He used huge doses, beyond the plateau range. On C3H mice, survival times of thirty-six to forty-eight, and twelve to twenty-four hours, respectively, were recorded after doses of 25,000 and 50,000 r. On subjecting the animals to radiation at a rate of 7,000 to 10,000 r per minute, death was observed in twenty-two minutes from the start of the experiment. Our own findings agree in general with Henshaw's, only we found the hyperacute reaction in a somewhat lower dosage range.

This short survey shows that each phase of the reaction has been studied before: the phases we call subacute, acute, and

hyperacute are all known. However, the segmental character of the dose-response relation has not been brought out, nor has the presence of the plateaus been established.

Histopathological studies have not gone very far to explain the mechanism of roentgen death. Several explanations have been offered; none has been generally accepted. Several tissues and organs show severe changes, and have, in turn, been considered as the decisive factor. We do not believe that pathological findings can resolve this conflict of opinion.[4,5,6,7,8,10]

The segmentation of the dose-response curve suggests that there is more than one mechanism involved in roentgen death. A very simple explanation of the segmentation of the curve is that there are three separate reactions. A first reaction has a maximum response corresponding to the subacute plateau; a second reaction has a threshold at 600 r and a maximum response at three and one-third days, corresponding to the acute plateau; a third reaction has a threshold around 8,000 r and a response which is not bounded by a maximum value.

Observations other than survival times support the idea of distinct mechanisms corresponding to the three phases. Subacute and acute reactions are differentiated by the weight curve which is biphasic in the former, monotone in the latter, and by the pathological picture; acute and hyperacute reactions are differentiated by the motor symptoms.

Our observations have not disclosed any specific information about the mechanism of roentgen death. They have strongly suggested that more than one mechanism is involved, different reactions dominating in different dosage ranges. It seems, however, that their number is limited, probably to three. Thus it can be hoped that the problem, while certainly not simple, is not exceedingly complex.

SUMMARY

1. Mice of 20 gm. weight were irradiated with roentgen rays. The doses ranged from 500 to 25,000 r. The tissue doses were about homogeneous throughout the whole body.

2. The reactions produced are classified as subacute, acute, and hyperacute reactions.

3. The survival time (between irradiation and death) is used as a quantitative measure of the irradiation effect. To characterize the reaction of a whole class of mice we use the mean logarithmic survival time, or the almost identical median survival time, i.e., the time after which one-half of all fatalities have occurred.

4. The relation between survival time and dose administered shows four zones with distinctive dose-response characteristics. There are two zones where the survival time decreases with increasing dose, and two plateaus where the survival time remains constant over considerable dosage ranges.

5. Simple mathematical formulae for the survival time-dosage relations are given.

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REFERENCES

1. Chase, H. B. Studies on anophthalmic strain of mice. III. Results of crosses with other strains. *Genetics*, 1942, *27*, 339–348.
2. Ellinger, F. Lethal dose studies with x-rays. *Radiology*, Feb., 1945, *44*, 125–142.
3. Ellinger, F. Goldfish as new biologic test object in experimental radiation therapy. *Radiology*, 1940, *35*, 563–574.
4. Henshaw, P. S. Experimental roentgen injury; effects on tissues and blood of C3H mice produced with single small whole-body exposures. *J. Nat. Cancer Inst.*, 1944, *4*, 477–484.
5. Henshaw, P. S. Experimental roentgen injury: changes produced with intermediate-range doses and comparison of relative susceptibility of different kinds of animals. *J. Nat. Cancer Inst.*, 1944, *4*, 485–501.
6. Henshaw, P. S. Experimental roentgen injury; tissue and cellular changes brought about with single massive doses of radiation. *J. Nat. Cancer Inst.*, 1944, *4*, 503–512.

7. Henshaw, P. S. Experimental roentgen injury; effects of repeated small doses of x-rays on blood picture, tissue morphology, and life span in mice. *J. Nat. Cancer Inst.*, 1944, *4*, 513–522.
8. Lawrence, J. H., and Tennant, R. Comparative effects of neutrons and x-rays on the whole body. *J. Exper. Med.*, 1937, *66*, 667–688.
9. Sugiura, K. Effect of roentgen rays on growth of mouse sarcoma 180 irradiated in vivo. *Radiology*, 1937, *28*, 162–171.
10. Warren, S. Effects of radiation on normal tissues. *Arch. Path.*, 1942, *34*, 443–450; 562–608; 749–787; 917–931; 1070–1084. *Ibid.*, 1943, *35*, 121–139; 304–353.

Vol. 54, No. 5

STUDIES ON ROENTGEN DEATH IN MICE*

II. BODY WEIGHT AND SENSITIVITY

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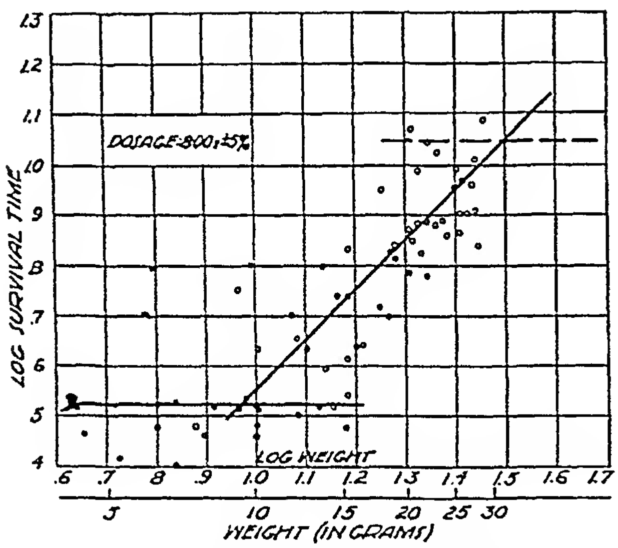
INTRODUCTION

In the first paper[2] of this series, the relation between roentgen dose administered and survival time was established for mice of a standard weight. In the present, the second paper, the discussion will be extended to mice of various weights. It will be shown that the reactions which occur in mice of different weight are identical, but that the doses necessary to elicit a given response vary with the weight. Thus, the body weight is a factor determining the sensitivity to roentgen rays. In terms of the graph, a change of body weight causes the whole dose-response curve to shift parallel to the dosage axis.

C57-Black mice were used for this investigation. The methods of irradiation and observation were the same as described in the preceding paper.[2]

EFFECTS OF CONSTANT DOSES ON MICE OF VARYING WEIGHT

The effect of weight on survival time was studied on sixty-seven C57-Black mice, aged twenty-five days or more, which were subjected to doses from 760 to 841 r, using the sets of conditions A, B, C, D, E, and F of Table I in the preceding paper.[2] The survival times between irradiation and death were recorded, and the data obtained assembled in Figure 1. Every symbol represents an individual observation; its position indicates weight at the time of irradiation, and survival time. It was found that for mice up to 9.5 gm., the survival time is



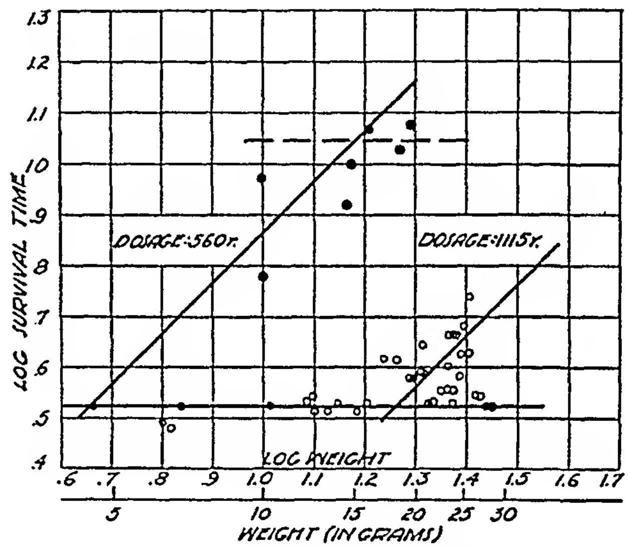


Fig. 1 and 2. Survival time as a function of weight, for constant doses. Circles represent individual observations, heavy lines the estimated trends. Fig. 1, doses of 800 r, 5 per cent; Fig. 2, doses of 560 and of 1,115 r. The scales in these (and all the other graphs except Fig. 3 and 4) are logarithmic for greater ease in presentation. The formulae and figures in the text are numerical.

about three and one-third days, a plateau value established in the preceding paper.[2] For mice of greater weights, the survival times are directly proportional to the weight. In the transitional zone, between the two segments of the curve, there is the same appearance of uncertainty which was observed in the transitional zones of the curve showing the effect of various doses on mice of a given weight.

Similar results were obtained with higher and lower doses. Figure 2 shows the survival times observed in 40 mice after administration of 1,110 and 1,120 r (settings

* From the Department of Radiology, Carle Hospital Clinic, Urbana, Illinois.

D and F), and the survival times in 7 mice killed out of 10 irradiated with doses of 558 and 560 r (settings A and F). With the low doses, the entire weight range studied corresponds to the sloping segment of the curve, whereas with the high doses, the plateau extends up to near the upper limit of the weight range.

qualitatively the same as in the zone of the acute reaction. Lighter mice die earlier than heavier ones in both zones.

To summarize the influence of weight on survival time: In regions where the response changes with varying dose, mice will survive longer in proportion to their weight after administration of equal doses; or, to

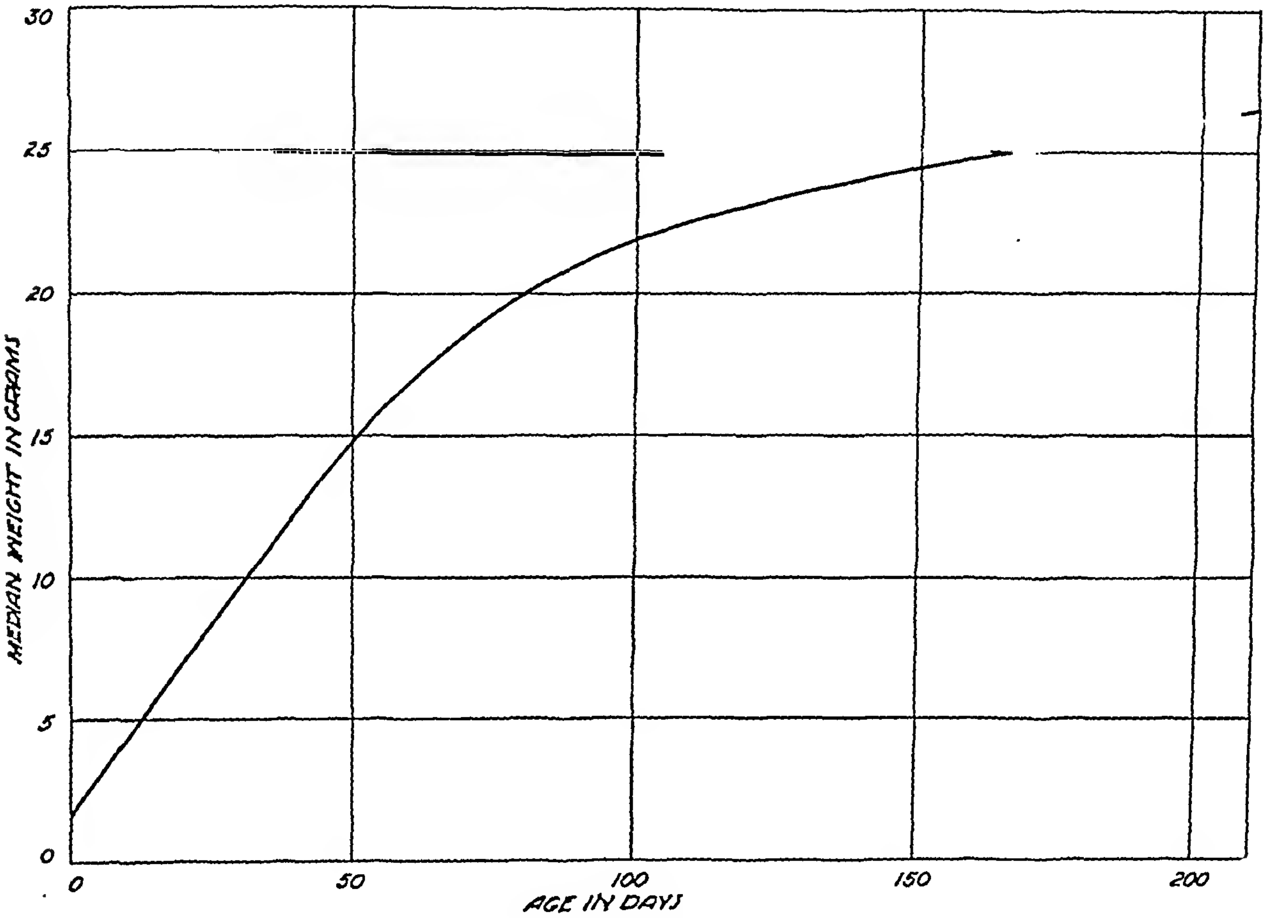


Fig. 3. Age and median weight (C57-Black mice).

In mathematical terms, the relation between survival time and weight, at a given dosage, can be expressed as follows:

2.1 $T = 3\frac{1}{3}$ days $(W \leqq A)$

2.2 $T = k.W$ $(W > A)$

where T is the survival time between irradiation and death, W the weight at the time of irradiation, and k and A are functions of the dosage.

For the zones of the subacute and hyperacute reactions we have not enough observations to formulate the results quantitatively. It can be stated, however, that in these two zones the situation is at least

obtain equal survival times, the doses have to be higher for the heavier mouse. On a plateau level, large and small mice die at the same time provided the dose is within the plateau range for all of the mice tested.*

WEIGHT AND AGE IN THEIR RELATION TO EACH OTHER AND TO SENSITIVITY

The mice used in our experiments were up to seven months old, the median weight increasing with age as shown in Figure 3.†

* Ellinger[1] has found no relation between survival time and weight in goldfish, but he does not state whether or not the dosage used was within the plateau range.

† The median weight divides the mice of any given age class into a heavy and a light group of equal size. The curve given is

From the two known relations, that between age and weight and that between weight and survival time, one can calculate the relation between age and survival time. This was done for a dosage of 800 r. Figure 4 shows the hypothetical curve of the age-survival time relation, together with symbols representing actual observations. Considering first only mice twenty-five or more days old, we see that the actual observations are near the expected values. The amount of scattering is about the same as that observed for the weight-survival time relation. Thus, age or weight could be used equally reasonably to predict the reaction of a given mouse to a given dosage. We use weight because it leads to a much simpler mathematical expression than age would.

For very young mice, those under twenty-five days old, the statement that sensitivity decreases with increasing weight does not hold true. Infant mice survive a given dose considerably longer than adult mice (dashed line in Fig. 4). A detailed discussion of these anomalous responses will be given in a later paper.

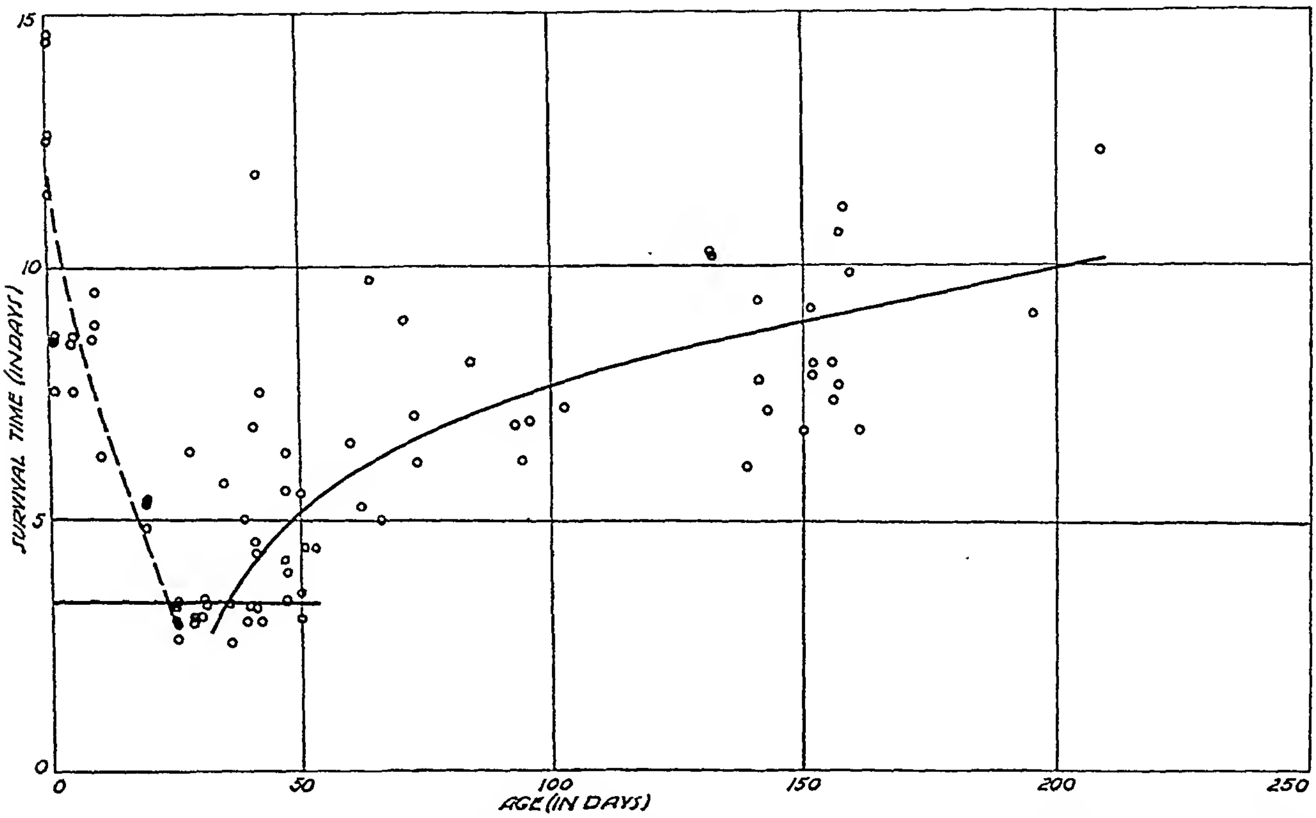


Fig. 4. Survival time and age. Symbols represents individual observations; full lines the trend as predicted from the two relations, between survival time and weight, and between weight and age; the dashed line the trend found in infant mice.

not identical with the growth curve of any given mouse. Individual growth curves show an inflexion at about 15 gm. which is much sharper than that of the "median weight" curve. Also, they often show irregular oscillations around the region of inflexion.

THE MEDIAN SURVIVAL TIME AS A FUNCTION OF DOSAGE AND WEIGHT

Combining the relations between dosage and survival time at a constant weight,

1.2 ... $T.D^2=4.64\times10^6$ ... ($D\leqq1175$ r for mice of 20 gm.)

1.3 ... $T=3\frac{1}{3}$ days ... ($D>1175$ r)

and between weight and survival time at a constant dosage,

2.1 ... $T=3\frac{1}{3}$ days ... ($W\leqq A$)

2.2 ... $T=k.W$ ... ($W>A$)

we obtain the following formulae for the relation between survival time, dosage, and weight:

$$T.D^2/W=2.3\times10^5 \quad (D^2/W\leqq6.9\times10^4\ \text{r}^2\text{gm}^{-1})$$
$$T=3\tfrac{1}{3}\ \text{days} \quad (D^2/W>6.9\times10^4\ \text{r}^2\text{gm}^{-1})$$

and, assuming that the survival time-weight relation holds true for all four seg-

ments of the dose-response relation, we get the set of formulae:

2.3 ... $T = 11\frac{1}{4}$ days
... $(D^2/W \leqq 2.1\times10^4 r^2\ gm^{-1})$

2.4 ... $T.D^2/W = 2.3\times10^5$
... $(2.1\times10^4 < D^2/W \leqq 6.9\times10^4\ r^2\ gm^{-1})$

2.5 ... $T = 3\frac{1}{3}$ days
... $(6.9\times10^4 < D^2/W \leqq 6.7\times10^6\ r^2\ gm^{-1})$

2.6 ... $(\log T - 1.05)\times(\log D^2/W - 7.8) = 0.25$
... $(6.7\times10^6 < D^2/W)$

6. The observations are scattered around the mean, 2.3×10^5, with a standard deviation of 19 per cent. The distribution is skew but this might not hold true with a larger number of observations. A small part of the scatter can be traced to the experimental factors, errors in the determinations of dose and survival time, and incidental fluctuations of the weight. However, the largest part of the deviations, about 17 per cent, is unaccounted for.

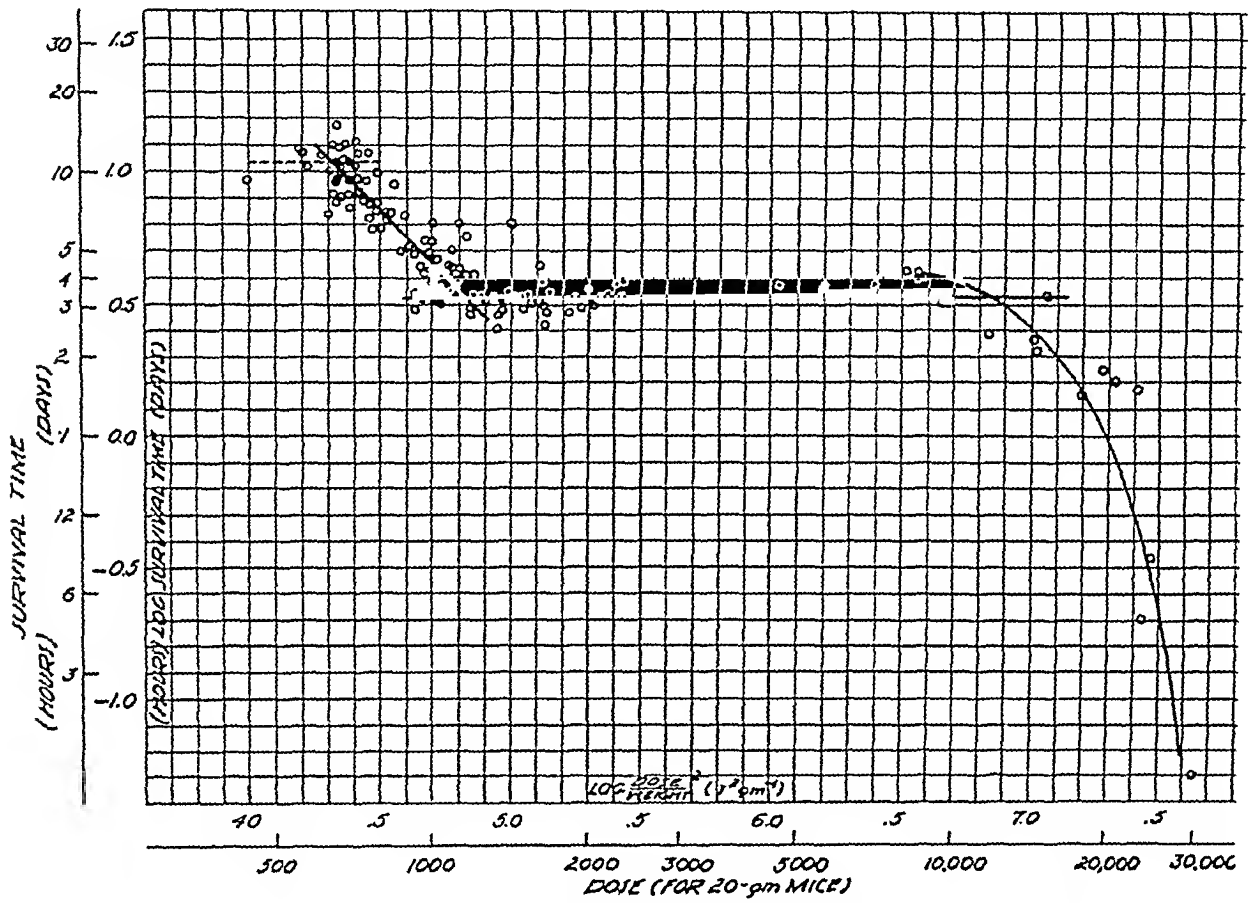


Fig. 5. Survival time as a function of the quotient "squared dose over weight."

These formulae are represented by heavy lines in Figure 5. The symbols indicate 202 individual observations in C57-Black mice. The agreement between observed values and the curve is good.

A quantitative study of agreement between observed and expected values was performed for the second, sloping segment of the curve. In this zone, the dose-response relation is expressed by the formula, $T.D^2/W$ equals a constant. Excluding the transitional zones, we find 33 mice in this region. The actual values, $T.D^2/W$, observed in this group, are entered in Figure

DISCUSSION

The investigation of survival times in relation to weight and dosage has demonstrated two facts: adult mice of various weights show essentially the same reactions, with identical plateau values; and heavier mice are less sensitive than lighter ones. For given doses, the quotient of survival times equals the quotient of the respective weights, provided the survival times are off the plateaus.

As far as we know, no such definite relation between body weight and roentgen-ray effects has been established before. A weight factor like the one we discussed appears very commonly in the study of drug actions. But it must be remembered that the quotient dose (of a drug) per body weight, in pharmacology, is analogous to the plain dose in total body irradiation. Both indicate the average concentration of an agent in the body tissues.* Thus, the explanation of the protective influence of weight is not obvious.

A possible relation which we have to discuss is the one between speed of growth and sensitivity. It is generally true that the faster a tissue grows, the more sensitive it is to radiations. It is also true that the heavier a mouse is, the slower its growth, and the lower its sensitivity to roentgen rays. Yet, it is highly improbable that a direct connection between sensitivity and speed of growth exists. The growth curves show sharp inflexions around 20 gm., and these inflexions turn up whether we consider the absolute or the relative speed of growth. But they are not reflected in any comparably sudden change of sensitivity. Besides, there is the anomalous behavior of infant mice. They respond to irradiation less than adult mice, yet their growth is very vigorous. Thus, there cannot be any simple connection between growth and sensitivity.

SUMMARY

1. The survival time, after administration of constant doses, is proportional to the weight, provided the survival time is between eleven and one-fourth and three and one-third days.

2. The two plateaus, at eleven and one-fourth and three and one-third days, occur in adult mice of all weight classes.

3. The three relations, between age and sensitivity, between age and weight, and between weight and sensitivity, are concordant in adult mice.

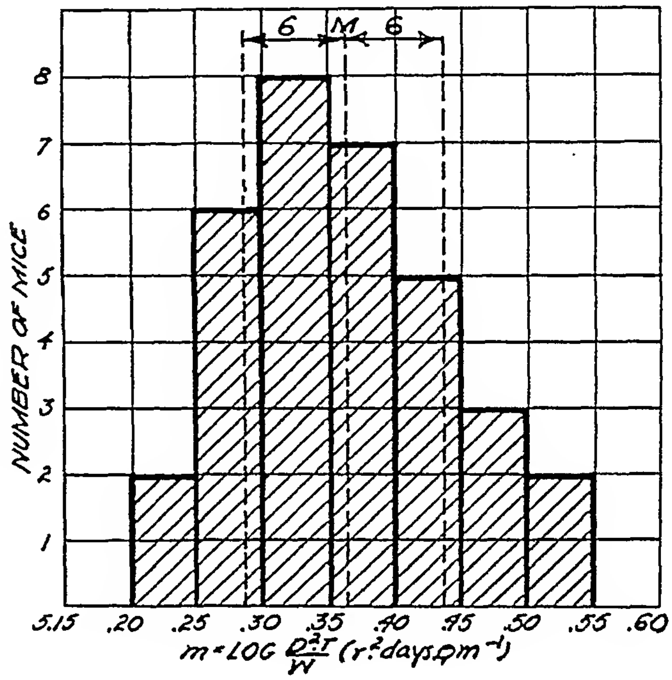


Fig. 6. Distribution of the value "squared dose by survival time over weight" in thirty-three C57-Black mice.

4. Infant mice survive longer than adult mice after application of the same dose.

5. Simple mathematical formulae for the relations between dosage, weight, and survival time are given.

* The roentgenological term which compares to the plain "dose" in pharmacology is the volume dose, i.e., the integral of the dose distribution function over the irradiated volume. In total body irradiation, with homogeneous dosage distribution, the volume dose equals the product of dose by body weight.

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REFERENCES

1. Ellinger, F. Goldfish as new biologic test object in experimental radiation therapy. *Radiology*, 1940, *35*, 563–574.

2. Quastler, H. Studies on roentgen death in mice. I. Survival time and dosage. Am. J. Roentgenol. & Rad. Therapy, Nov., 1945, *54*, 449–456.

PNEUMOROENTGENOGRAPHY WITH OXYGEN IN THE DIAGNOSIS OF INTERNAL DERANGEMENTS OF THE KNEE JOINT*†

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THE use of contrast roentgenography in the diagnosis of internal derangement of the knee joint is by no means an original subject. Its use as an adjunct to clinical examination has been described previously.[1,2,4,5]

Because of the frequency with which we were encountering disability of the knee joint, where the physical examination presented little evidence of a pathological condition and the routine roentgenograms were not helpful, we attempted to better visualize the intracapsular soft tissues of the knee by the introduction of oxygen into the synovial cavity.[4]

At first both knees were examined simultaneously. It seemed best to carry out the bilateral procedure on the first few cases until we became well acquainted with the normal appearances and variations of the knee joint as visualized by pneumoroentgenography.

We do not believe that the procedure should be used without serious consideration or that every case that comes to the clinic with knee complaints should be subjected to it. However, in those cases where clinical evaluation is not conclusive, the method is thought to have definite diagnostic value.

In our series, 25 cases were examined, of which 18 knees were thought to show some abnormality. Of these 18, three had had the meniscus removed previously, and the resulting pneumoroentgenograms were thought to clearly demonstrate the complete absence of the meniscus in 2 cases. One was thought to show a residual portion of the posterior segment of a previously removed cartilage. This was later proved by operation.

Of the remaining 14 where abnormality was demonstrated 10 came to operation. In 9 cases the operative findings agreed completely with the roentgen diagnosis.

Failure to make the correct diagnosis in the tenth case we feel was due to insufficient removal of synovial fluid. Thus "filling" with oxygen was incomplete and poor visualization of the internal structures of the knee resulted. We were hesitant about giving an opinion in this case, and it demonstrated to us the need for a good "filling" before this procedure can be of diagnostic value.

In an eleventh operative case no abnormality was demonstrated on the pneumoroentgenograms. However, the clinical picture so strongly indicated a pathological condition of the medial cartilage that the suspected meniscus was exposed by operation. A loose segment was found to be attached to the thin inner edge of the medial third of the cartilage. On review of the pneumoroentgenograms we did not feel we could honestly say the abnormality as found at operation was demonstrable on the pneumoroentgenograms.

The remaining 4 patients with abnormal findings in the pneumoroentgenograms either refused operation or the clinical aspect of the case did not warrant surgery.

ANATOMICAL CONSIDERATIONS

In studying the knee joint from the standpoint of pneumoroentgenography, the following anatomical considerations are considered worthy of mention.

* From the Departments of Surgery and Radiology, Royal Canadian Navy Hospital, Sydney, N. S.
† Prints of roentgenograms and photographs by the Royal Canadian Navy Photographic Section.

The articular surfaces of the condyles of the tibia are smooth areas on the upper aspects of these structures and are separated by the intercondylar eminence. In front and behind the latter are roughened depressed triangular areas. The mesial articular surface is oval and depressed in the center. The lateral is more circular in outline and the central portion tends to be *slightly elevated* rather than depressed like the medial one. This results in the lateral cartilage being visualized more readily than the medial one. The lateral surface is prolonged backward and downward over the posterior aspect where it comes in contact with the popliteus tendon.

The articular capsule is a complicated structure. In front, the ligamentous formation is made up by an expansion of the quadriceps extensor tendon which ensheaths the patella. Below, the central fibers form the thick patellar tendon which is attached to the tibial tuberosity. The more mesial and lateral fibers are attached to the anterior aspect of the tibial condyles.

The back of the joint is covered by a ligamentous network of intersecting bands which form a posterior ligament. There is an opening laterally for the escape of the popliteus tendon. From its attachment, to the lateral aspect of the external femoral condyle, this tendon runs backward, downward and medially to emerge from the joint posteriorly.

The medial collateral ligament or the tibial collateral ligament is a broad flat band. It is a true capsular ligament and its upper aspect is attached to the medial epicondyle of the femur with some fibers merging into the adductor magnus tendon. Distally the ligament is attached to the medial surface of the tibia. The deepest fibers of this structure have a shorter course and are attached firmly to the medial meniscus which is well demonstrated in the arthrogram.

The fibular collateral ligament, on the lateral aspect of the joint, is a cord-like structure that is *definitely separated from the capsular ligament.* It is attached above to the lateral epicondyle of the femur and below to the head of the fibula. The true capsular fibers have a definite space between them and the fibular collateral ligament. The outer fibers of the capsular ligament are shorter and weaker and bridge the space between the femoral and tibial condyles. The inner fibers are attached loosely to the periphery of the lateral meniscus except in its posterolateral aspect where the popliteus tendon separates these two structures.

The intra-articular ligaments are the an terior and posterior cruciate ligaments which are invested by the synovial membrane extending from the posterior aspect of the joint.

The anterior cruciate ligament arises from the mesial aspect of the roughened triangular surface between the anterior aspect of the two tibial condyles and run upward, backward and laterally to be inserted into the medial non-articular surface of the lateral femoral condyle. The posterior cruciate ligament arises from the lateral aspect of the posterior non-articular surface and runs upward, forward and medially to be inserted into the lateral non-articular surface of the medial condyle of the femur.

The two menisci or semilunar cartilages are interposed between the femoral and tibial condyles. Each is a wedge-shaped crescentic fibrocartilage. The thick outer borders are bound down to the peripheral margins of the articular surfaces of the tibial condyles by the short fibrous coronary ligaments. These borders are also fused to the deep aspects of the medial and lateral capsular ligaments. Thus, the medial meniscus is much more firmly attached to the corresponding collateral ligament than the lateral as previously described.

The synovial membrane is extensive and invests all surfaces. The joint is partially subdivided by these investments into upper and lower compartments by the menisci and into medial and lateral compartments by the patellar folds in front and the cruciate ligaments behind. This is of importance in the removal of fluid in preparation for the introduction of oxygen as these subdi-

visions tend to hold collections of fluid and thus prohibit good soft tissue visualization.

Three large recesses are usually found: the suprapatellar synovial pouch and one behind each femoral condyle. There is an extension of the synovial pouch of varying lengths along the popliteus tendon as it leaves the joint. This extension communicates occasionally with the synovial cavity of the upper tibiofibular articulation. Additional bursae or recesses are described in textbooks of anatomy but are not usually seen in the pneumoroentgenograms.

SURGICAL CONSIDERATIONS

Introduction of oxygen into the knee joint, while a minor surgical procedure, should be carried out in the operating room under aseptic technique.

The anterolateral approach to the joint has been used in all our cases. A point is taken on a level with the superior margin and about 1 cm. lateral to the lateral border of the patella. Under local novocain infiltration, a No. 20 gauge spinal needle is inserted into the skin at this point and directed downward and medially toward the center of the patella. On entering the joint, a diminution in resistance is noted much as in a spinal puncture. A spinal needle is used, because, due to its length, it is more easily directed and the stylet insures less damage to tissue.

When the joint has been entered, a syringe is applied and an attempt at aspiration is made. This should always be done, as unsatisfactory filling with oxygen will occur if there is increased fluid present.

Following attempted aspiration a 3-way stopcock is attached to the spinal needle. A sterile length of rubber tubing is inserted into one of the apertures of the stopcock by means of a glass or metal connecting piece, and the other end is handed to an orderly who attaches it to the outlet of an oxygen tank.

A dry 50 cc. glass syringe is now inserted into the other aperture of the stopcock. With the valve placed so that the oxygen tank communicates with the syringe, an assistant slowly releases the oxygen until the syringe plunger is pushed back to the 50 cc. or desired mark. The valve is then turned so that the syringe communicates with the spinal needle and joint cavity. It is necessary that the syringe plunger be dry so that any change in the resistance necessary to inject oxygen into the joint may be easily detected. It is for this reason that a separate syringe is used for attempting aspiration.

As the first part of the oxygen is being injected it has been found useful to note the medial parapatellar sulcus for bulging. This bulging, together with the ease with which the gas is injected, will indicate that the oxygen is entering the joint satisfactorily. Also, tapping the patella to elicit resonance is useful, and this sign is present after the injection of a very few cubic centimeters of oxygen.

It has been found that about 100 to 140 cc. is the optimum amount of oxygen necessary for good filling. However, as we progressed in our series, good filling was best obtained where our experience allowed us to assess the general bulging about the joint and the quality of resonance elicited on tapping the patella, rather than by injecting a measured quantity of oxygen.

Collodion is applied to the needle puncture site, and the patient taken to the roentgen department on a stretcher, arrangements having been made previously so that as short a time as possible elapses between injection of the oxygen and the taking of the pneumoroentgenograms. This time factor was not at first thought to be important, but we are satisfied that optimum roentgenological visualization is best obtained as soon as possible after the introduction of the gas.

Following roentgen examination the patients are returned to the ward with crepe bandages firmly applied. They are allowed up and about on the following day with no restriction of activities. Resonance on tapping the patella is present for about three to four days.

One patient developed an effusion four

days following the introduction of oxygen. Forty cubic centimeters of turbid fluid was aspirated. Large numbers of polymorphonuclear cells were present, but no organisms were found on smear or culture. Swelling regressed following aspiration and did not recur. No other complications following pneumoroentgenography have been encountered.

In 2 of our cases poor filling with gas was present in the symptomatic knee. Pneumoroentgenography was repeated, and in both cases abnormal amounts of fluid were present. Aspiration and reinjection of gas produced excellent pneumoroentgenograms. Thus, whether the presence of increased fluid content is suspected or not, aspiration should be attempted in every case prior to injecting oxygen.

PNEUMOROENTGENOGRAPHIC TECHNIQUE

A tight elastic bandage is applied to compress the suprapatellar recess and thus force as much gas as possible down into the joint space proper. The bandage should be applied starting well up above the knee gradually working down to include at least the upper half of the patella.

The exact position of the knee joint is located under the roentgenoscope and is well marked on both sides with skin pencil. It is considered better to apply the bandage before roentgenoscopy because of the relative change in position of skin and bone structures caused by the tight bandage. At this point it should be stated that if the knee joint does not appear to be well filled with gas under the roentgenoscope there is little use in going further with the examination. Careful observation at this time will save the roentgenologist considerable time.

The knee is next placed in an anteroposterior position over a specially built curved cassette holder (Fig. 1) which allows approximately 30° flexion of the joint. This dorsal position with the 30° flexion of the knee produces a spread of the joint space and thus better visualization of the internal soft tissue structures. It is believed that the curved film distorts the image in such a manner that the knee joint proper is widened to an appreciable extent. It is also considered that the use of the dorsal position and the curved cassette results in closer apposition of the joint to the film which allows finer detail on the pneumoroentgenogram. In this position it is easy to take the external and internal rotation

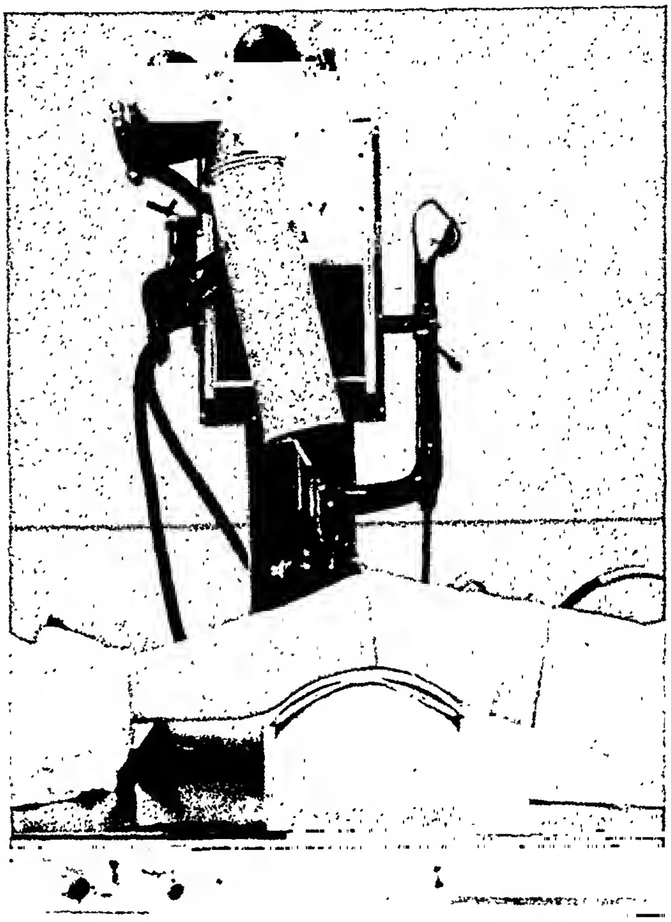

Fig. 1. The curved cassette holder with the cardboard film folder in place under the knee joint.

oblique views with a maximum of comfort and a minimum of movement.

The choice of the actual projections used rests with the roentgenologist concerned. Our routine projections were all stereoscopic sets in the dorsal, 45° external rotation, 45° internal rotation and true lateral views.

It was only after considerable experiment in different positions both with and without the curved cassette holder and in various projections that it was decided to use the above technique. The positioning as described by Cullen and Chance[2] was tried on a number of our cases. We found it gave

good visualization of one meniscus; however, it left much to be desired in demonstrating the other meniscus of the joint in question. Thus, since there is frequently some doubt as to which meniscus is involved the procedure is not used routinely.

All exposures were made with an extension cone of 10 cm. diameter at 30 inch focal skin distance, with 60 to 63 kv. (peak) at 100 to 125 ma-sec. on extra-speed film in cardboard holders. Where non-screen high speed film was used, which gave us better

Fig. 2. The pneumoroentgenogram of the right knee demonstrates the angulated uninterrupted air column extending along the tibial collateral ligament and the increased density between the lateral halves of the articular surfaces of the medial condyles.

soft tissue detail, 20 to 30 ma-sec. proved to be sufficient with the other factors unchanged. The central ray is projected through the previously marked joint space which requires a 10 to 15 tilt of the tube cephalad.

INTERPRETATION OF THE NORMAL PNEUMOROENTGENOGRAM OF THE KNEE JOINT

In the pneumoroentgenogram the cartilaginous covering of the bony articular surfaces is usually well demarcated and it is smooth and evenly distributed over all areas.

The numerous synovial folds and prolongations are best visualized in the lateral position. The most readily demonstrated are those behind the infrapatellar fat pad and in the posterior aspect of the joint. The suprapatellar recess contains a surprising amount of gas considering the pressure with which the bandages are applied as demonstrated in the left knee of Figure 4. Good filling of the pouch behind each femoral condyle is usually procured.

In the anteroposterior view the medial cartilage is not as well outlined in its entirety as the lateral, as illustrated in the right knee of Figure 4. This is due to its firmer attachments to the tibial collateral ligament which is well demonstrated. The short coronary ligaments bind this cartilage down tight to the tibial articular surface. Occasionally one sees a small air pocket under the mesial periphery of the cartilage as visualized in the left knee of Figure 7. The superior surface of the cartilage is really the only one well outlined and it can usually be easily differentiated from the articular surface of the medial femoral condyle again seen in the left knee of Figure 7. Normally the anterior and posterior horns of this cartilage are hard to demonstrate.

The lateral semilunar cartilage is usually better outlined than the medial. Its attachment to the lateral aspect of the capsule is visualized but is not as broad or firm as the corresponding one of the medial cartilage. An air column is usually seen to follow the popliteus tendon up behind these loose lateral attachments. This column demonstrates well the lack of fibers attaching the lateral meniscus to the lateral ligament of the capsule because of the interposition of the tendon. This is best seen in the oblique views of the left knee of Figure 3.

This cartilage frequently appears to ride higher in the joint space having only its weak lateral and its mesial anterior and posterior horn attachments. Thus both the superior and inferior borders of the meniscus are well visualized.

The cruciate ligaments can usually be demonstrated in respective positions. The anterior running upwards and laterally, the posterior upwards and medially. The latter is usually better visualized because of its more "end on" projection.

INTERPRETATION OF THE ABNORMAL PNEUMOROENTGENOGRAM OF THE KNEE JOINT

1. *Avulsion of the Internal Cartilage from*

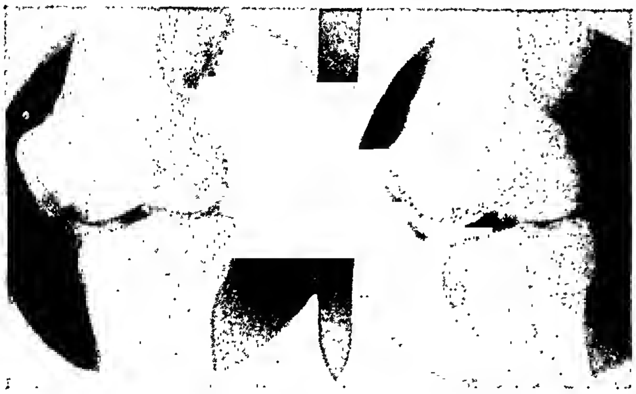

Fig. 5. The left knee exhibits well demarcated areas of increased radiolucency in the lateral condyle of the left femur just posterior to the tip of the patella.

the lateral femoral condyle was the interpretation of Figure 5.

At operation the left lateral cartilage was as described above and the areas of osteochondritis were confirmed. The medial meniscus was normal.

It is worth noting that this case clinically was considered to have medial meniscus abnormality and it was with considerable reservation that the incision was made to expose the lateral aspect of the joint.

4. *Loose Bodies, Pedunculated or Otherwise, in the Knee Joint.* In this case no definite abnormality was at first seen in the pneumoroentgenograms. However, as the patient had such definite clinical symptoms the knee joint was opened on the medial side. A pedunculated loose portion of the anterior segment of the medial cartilage was found.

Fig. 6. Note the triangular shaped shadow above the inner aspect of the internal semilunar cartilage.

The appearance of the internal oblique pneumoroentgenograms (Fig. 6) would, we feel on review, support such a diagnosis. In these films a triangular shaped area of increased density is noted above the inner portion of the medial cartilage. This, it is believed, is the shadow of the loose portion of the cartilage found at operation.

Since the above case we have had 2 cases which at operation exhibited a similar condition. One case was diagnosed by pneumoroentgenography, the other was not.

Fig. 7. In the right knee the absence of cartilage shadow and the uninterrupted air column are characteristic of the joint appearance following removal of the cartilage.

5. *Surgically Removed Cartilage.* Cases that have had a cartilage removed resemble very much the avulsion type as described in Figures 2 and 3.

In the true dorsal and the dorsal oblique pneumoroentgenograms there is visualized an interrupted column of air inside the lateral capsular ligament. There is lack of soft tissue shadow between the articular surfaces of the condyles. All these points are demonstrated in the accompanying right pneumoroentgenogram (Fig. 7).

SUMMARY

In the cases presented the classical symp-

toms of internal derangement of the knee were not exhibited. In some instances the acute symptoms had subsided and the physical examination presented very little evidence of a pathological condition. Thus we were dependent to a great extent on the history of previous episodes. In an attempt to avoid long periods of observation in the hospital, these patients were subjected to oxygen pneumoroentgenography. It is believed that this procedure has facilitated an early decision relative to surgery in these cases.

We have found the following points to be of diagnostic value in the interpretation of pneumoroentgenograms of the knee joint:

1. Roughening and narrowing of cartilage surfaces, either articular surface coverings or the semilunar cartilages as visualized in the left knee of Figures 4 and 5.

2. Uninterrupted gas columns along the inner aspect of the collateral ligaments of the joint where capsular structure should be firmly attached to the periphery of the menisci. This is demonstrated in Figures 2, 4 and 7. The normal gas column presented on the posterolateral aspect of the knee joint by the popliteus tendon should be kept in mind.

3. Increase in the soft tissue (increased density) in the intercondylar or non-articular region of the joint with a corresponding lack of density in the lateral or medial region, as demonstrated in Figures 2 and 4.

4. Separation of the meniscus shadow from the contiguous bone structures illustrated in Figure 3.

5. Loose or semi-loose bodies calcified or otherwise shown in Figure 4.

6. Joint space narrowing as visualized in Figure 4.

7. Exostosis and eburnation of the articular surfaces as seen in Figures 4 and 5.

The last three findings can be demonstrated on routine reontgenograms of the knee. In each of our cases the ordinary roentgenograms were taken and although such conditions were suspected they were by no means as convincingly demonstrated as following the introduction of oxygen. This is more applicable to cases with early pathological changes of these types.

It has been of interest to us to demonstrate that the amount of cartilage left along the capsular attachment in the bucket-handle fracture has been much less than we would anticipate from the appearance of the pneumoroentgenogram.

The lack of mention of any cruciate abnormality will of course be noted. None of our cases thus far encountered were thought to demonstrate definite cruciate abnormality on the pneumoroentgenograms nor were any such lesions found at operation. Thus, we are unable to give any information at this time with reference to cruciate ligament injury.

CONCLUSIONS

1. Oxygen pneumoroentgenography is a useful adjunct in the diagnosis of obscure internal derangements of the knee joint.

2. It should not be used routinely but only in those cases which present a difficult diagnostic problem.

3. Calcified and more especially non-calcified loose or semi-loose bodies (joint mice) are clearly demonstrated.

4. The procedure when performed under aseptic surgical conditions carries little risk of complications.

5. The use of the curved cassette holder and multiple stereo projections has, in our opinion, increased the accuracy and usefulness of this procedure.

REFERENCES

1. Quaintance, P. A. Pneumoroentgenography of the knee joint. *J. Bone & Joint Surg.*, 1938, *20*, 353–362.
2. Cullen, C. H., and Chance, G. Q. Air arthrography in lesions of semilunar cartilages. *Brit. J. Surg.*, 1943, *30*, 241–245.
3. Cunningham, D. J. Text-Book of Anatomy. Sixth edition. William Wood & Co., New York, 1931.
4. Kleinberg, S. Injection of oxygen into joints for diagnosis. *Am. J. Surg.*, 1921, *35*, 256.
5. Simon, H. T., Hamilton, A. S., and Farrington, C. L. Pneumoradiography of the knee; newer technic demonstrating its value in diagnosis of semilunar cartilage injury. *Radiology*, 1936, *27*, 533–540.

MINIATURE CHEST FLUOROGRAPHY WITH CONTROL STUDY*

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MANY reports have appeared in the literature in recent years to indicate the value of miniature chest fluorography for the detection of pulmonary tuberculosis. Relatively few studies have been made to confirm the accuracy of this method by simultaneous roentgenography with the conventional 14 x 17 inch film. Potter, Douglas and Birkelo[9] examined 1,610 clinic attenders in this manner using single 4 x 5 inch films as the miniature record. These patients either had symptoms of tuberculosis, had been exposed to it, or had had a positive skin test for tuberculosis. There was only a 2.6 per cent error in detecting 271 cases with active tuberculosis as found on the full size film. Bridge[1] found 259 cases of significant tuberculosis out of 1,000 consecutive cases examined by single 4 x 5 and 14 x 17 inch films in a tuberculosis dispensary. Two, or 0.77 per cent, of these cases were missed on the miniature films and of the 130 minimal lesions, 2, or 1.5 per cent, were in error on the smaller films. Plunkett, Weber and Katz[7] examined 1,000 patients in a mental hospital utilizing 35 mm., 4 x 5 and 14 x 17 inch films on each subject. On the 35 mm. films 91.8 per cent of clinically significant tuberculosis was detected and on the 4 x 5 inch films 98.3 per cent was found. In this study, the detection of minimal lesions was accurate in 82.6 per cent in the 35 mm. and 96.6 per cent in the 4 x 5 inch films.

The purpose of this communication is to submit further evidence of the accuracy of findings in 1,000 subjects consecutively examined by the 4 x 5 inch miniature method in comparison with the 14 x 17 inch film used in regular practice. It is generally agreed that the use of stereoscopic 14 x 17 inch roentgenograms is the most accurate method for the diagnosis of minimal pulmonary tuberculosis. Christie[2] and de Lorimier[3] are of the opinion that stereoscopic 4 x 5 inch fluoroscopic roentgenograms are of greater diagnostic accuracy than a single 14 x 17 inch roentgenogram because the shift of the roentgen tube will uncover small lesions hidden under the rib shadows. The present study indicates that even the single 14 x 17 inch roentgenogram is superior in diagnostic qualities to the stereoscopic 4 x 5 inch miniature.

A photoroentgen unit was installed in the Department of Roentgenology at the University Hospitals of Cleveland to reduce the cost entailed in examining the chests of employees who constitute an unselected, apparently healthy adult group. While it was realized that the 35 mm. unit has certain advantages over other types of miniature apparatus, such as in reduced cost, speed of operation and smaller filing space of films, the 4 x 5 inch type was nevertheless selected because it seemed to be more practicable for our purpose based on the experience of other workers (Christie, de Lorimier, Plunkett, Weber and Katz, Bridge, and Potter, Douglas and Birkelo). The cost of the smaller film is about one-sixth that of the conventional size without consideration of the saving in processing.

Miniature and large roentgenograms were simultaneously obtained on the first thousand asymptomatic subjects consecutively examined.

TECHNIQUE

Experimentation with this new method of examining chests demonstrated that certain technical factors are more exacting

* From the Department of Roentgenology of The University Hospitals of Cleveland and the School of Medicine of Western Reserve University. Presented at the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, Chicago, Ill., Sept. 24–29, 1944.

than in conventional roentgenography in order to obtain satisfactory results. Emphasis is placed on accurate measurements of the anteroposterior diameter of the chest for variations in kilovoltage and on precise centering of the patient's chest against the screen support. The only variable factor is peak kilovoltage which ranges between 61 and 74. The constant factors include a current level of 300 milliamperes, 42 inch focal-screen distance, $\frac{1}{5}$ second exposure time, fine mesh stationary grid (50 lines per inch) and single emulsion film. The apparatus employed is the photoroentgen unit manufactured by the General Electric X-Ray Corporation for stereoscopic 4 x 5 inch films (single film in 4 x 10 inch holder). The fluorescent screen is composed of large crystals of zinc sulphide which has seven times greater illumination than the ordinary fluoroscopic screen. The camera lens is rated at F 1.5. Our own experiments with single and double emulsion films with and without a grid corroborate the findings of Potter[8] and de Lorimier[3] in that the most satisfactory roentgenogram from the standpoints of contrast and detail is obtained with the single coated film in conjunction with a grid. Equivalent results are obtained with either the Eastman or DuPont brand of film. Examinations of chests with anteroposterior diameters greater than 25 cm. were rejected since our experience, as well as others (Pindell[6]), has shown results to be uniformly poor.

Film manufacturers have advocated a slight increase in developing time for improvement in contrast. We have found that a slight increase in kilovoltage over the measured normal with developing time the same as for the average roentgenogram produces a slightly "underdeveloped" appearing film of improved diagnostic qualities.

The roentgenographic apparatus used in conjunction with the photoroentgen unit consisted of a General Electric K x 8 500 milliampere transformer with impulse timer and rotating anode tube of 2 mm. focal spot.

A specially designed stereoscope (orthostereoscope) is used for viewing 4 x 5 inch stereoscopic photoroentgenograms, giving the viewer the effect of scanning a 14 x 17 inch roentgenogram at a 40 inch distance. The position of the lenses is fixed in relation to films with adjustment allowed for different interpupillary distances.

Table I

Original Interpretation				
	14" x 17"	Errors 14" x 17"	4" x 5"	Errors 4" x 5"
Minimal pulmonary tuberculosis	23	1	20	4
Classification of Lesions After Review				
Active minimal tuberculosis	17	0	16	1
Inactive minimal tuberculosis	7	0	7	0

STATISTICS

The interpretations of the two sizes of roentgenogram were equally divided between the authors and the results compared later. One of us made reports on the first 500 fluorograms while the other interpreted the large roentgenograms made on the same employees. The procedure was reversed between us for the second series of both types of roentgenograms. Recordings were made on form sheets according to Hodges.[4]

In the interpretation of the miniature roentgenograms, the lesions were not classified as active or inactive. Only after review of the two sets of roentgenograms was this

classification made (Table I). Of the cases examined 602 were females and 398 were males. The average age for both sexes was twenty-nine years, the females being twenty-six and the males thirty-three. The oldest was seventy-two and the youngest fifteen years of age. There were 24 cases of pulmonary tuberculosis, all of minimal extent, in the 1,000 subjects examined. Of these 24 cases, 11 were females and 13 were males. This incidence is higher than is ordinarily found in the adult population at large and may be accounted for by the large number of student nurses in this group.

TABLE II

	14"x17"	4"x5"
Small shadows incorrectly called questionable tuberculous lesions	4	6

One error was made in the interpretation of the 14 x 17 inch roentgenogram while 4 errors were accounted for in the group of miniatures. In the review study, the lesions were classified as active and inactive minimal lesions, there being 17 of the former and 7 of the latter group (Table I). Only one error was found on a miniature after the roentgenograms had been carefully compared. This roentgenogram failed to demonstrate the lesion even though it was readily observed on the large roentgenogram. The reason was due to a slight difference in angulation.

In this study there were several small shadows called questionable tuberculous lesions which on review proved to be incorrectly interpreted (Table II). Two of these shadows proved to be blood vessels seen on cross section. Four others were calcified tuberculous foci. One of these cases was incorrectly interpreted on both the 14 x 17 and 4 x 5 inch roentgenograms. Such shadows, even though considered a questionable lesion, should be checked by large roentgenograms until greater experience in this type of work is gained.

A considerable number of diseases of the chest other than pulmonary tuberculosis were also found in this study. They include diseases of the heart and great vessels, pleural scarring, anomalies, pneumonia, acquired bone lesions, mediastinal masses, scoliosis, sarcoidosis, fibrosis of the lung, bronchiectasis, spontaneous pneumothorax and lung tumor. Table III gives the number of these lesions.

TABLE III

Diseases of heart and great vessels	22	Scoliosis	5
Pleural scarring	18	Sarcoidosis	2
Anomalies	17	Fibrosis of lung	2
Pneumonia	10	Bronchiectasis	1
Acquired bone lesions	7	Spontaneous pneumothorax	1
Mediastinal mass	5	Lung tumor	1

SUMMARY

1. Many studies have been made to indicate the value of miniature chest fluorography, but only a few comparison studies with 14 x 17 inch roentgenograms have been reported.

2. Further evidence is submitted as to the accuracy of stereoscopic 4 x 5 inch miniature fluorography by the examination of the chests of 1,000 symptomless adult hospital employees with conventional roentgenographic control.

3. Precision in technique is necessary in miniature fluorography if satisfactory results are to be obtained.

4. Twenty-four minimal pulmonary tuberculous lesions were detected in 1,000 examinations. Four errors were made in the first interpretation of the miniature films. Only one error was recorded on review of both sizes of films indicating the accuracy of the method.

5. Experience in the interpretation of miniature films is necessary for the highest degree of accuracy.

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REFERENCES

1. Bridge, E. Case-finding with fluoroscopic roentgenography. *Am. Rev. Tuberc.*, 1940, *42*, 155–160.
2. Christie, A. C. Evaluation of methods for mass survey of chest. Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 76–82.
3. de Lorimier, A. A. Mass roentgenography of chest for the United States Army. *Radiology*, 1942, *38*, 462–472.
4. Hodges, F. J. Fluorographic examination of chest as a routine hospital procedure. *Radiology*, 1942, *38*, 453–461.
5. Marinaro, N. A., and Phelps, P. S. Photoroentgenography in tuberculosis case finding. *Connecticut M. J.*, 1942, *6*, 948–950.
6. Pindell, M. L. Photoroentgenography in a tuberculosis program. *Radiology*, 1942, *38*, 224–231.
7. Plunkett, R. E., Weber, G. W., and Katz, J. Comparative value of roentgen-photographic methods. *Am. J. Public Health*, 1941, *31*, 772–776.
8. Potter, H. E. Technical factors underlying miniature roentgenography of the chest. Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 71–75.
9. Potter, H. E., Douglas, B. H., and Birkelo, C. C. Miniature x-ray chest film. *Radiology*, 1940, *34*, 283–291.

MILIARY CARCINOSIS OF THE LUNGS SECONDARY TO PRIMARY CANCER OF THE GASTRO-INTESTINAL TRACT

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MILIARY carcinosis of the lungs from cancer of the gastrointestinal tract, biliary tract and pancreas is not common. There are certain pathologic and anatomic reasons for this. These will be discussed briefly and then the necessary variations to produce miliary carcinosis will be formulated.

Of course, miliary carcinosis to the lungs requires blood stream dissemination of tumor cells to the right heart. Venous return from the gastrointestinal tract and associated structures passes by the portal vein to the capillary bed of the liver which, at least theoretically, should filter out tumor cell emboli in most instances with subsequent formation of secondary liver lesions. Thus, by this route, the tumor cells would not reach the pulmonary circulation. Lymphatic spread or direct extension alone could not possibly account for miliary pulmonary distribution. Pulmonary spread by lymphatics through the diaphragm could occur but the appearance in this case would not be that of miliary carcinosis either roentgenographically or pathologically. Rather, it would resemble the lymphatic pulmonary extension seen in cancer of the breast. Metastatic spread of cancer of the gastrointestinal tract is predominantly lymphatic as in other malignant tumors of epithelial origin. Such a spread is first to the regional lymph nodes. From there extension to the thoracic duct may occur with any degree of extension up this trunk. This extension into the neck accounts for the occurrence of a Virchow's node in malignant tumors of the gastrointestinal tract. Tumor cell emboli may pass from the thoracic duct to the left subclavian vein, to the left innominate, to the superior vena and then to the right heart where a massive blood stream dissemination to the lungs may occur. By this mechanism outlined above we have our first method of pulmonary miliary carcinosis from the gastrointestinal tract.

A second method is perhaps more common. If an extension from a primary gastrointestinal malignant tumor invades the liver and then the hepatic veins, multiple tumor cell emboli may enter the venous circulation and pass directly to the right heart and then to the pulmonary fields. Such a condition may be set up by direct extension to the liver as in cancer of the gallbladder or by secondary blood stream metastases by the portal circulation to the liver. Actual invasion of the hepatic veins can usually be demonstrated pathologically in these cases which show spread to the lungs.

It must be noted at this time that either of the above mechanisms may result in isolated pulmonary metastases and it is only when a large shower of tumor cells passes into the circulation that we have the necessary condition set up for an actual miliary carcinosis. Also we may have all variations between an isolated metastasis and a miliary carcinosis. This paper deals only with cases which exhibited a definite miliary carcinosis.

Secondary pulmonary extension may in some cases somewhat obscure the primary picture. This extension may be lymphatic or even bronchiogenic as tumor cells invade the alveoli and smaller bronchi.

Achard, Bariéty, Desbuquois and Sternfeld[1] in 1931 published a case of miliary carcinosis from a cancer of the stomach in which they concluded that the metastases were entirely of lymphatic spread. Desbuquois[2] published a second similar

case in 1935 with similar conclusions. Such a type of spread is not generally thought of in miliary carcinosis to the lungs although secondary involvement of pulmonary lymphatics is not uncommon, as has been mentioned previously. It would seem that anatomically a true miliary carcinosis must depend on blood stream dissemination through the right heart, the same as in miliary tuberculosis.

CASE REPORTS

Case I. Mrs. L. D., female, white, aged sixty-three, admitted to the hospital on December 8, 1935. For one year previous to admission the patient had had intermittent dull pain in the left costovertebral angle and interscapular areas. She had also had occasional low abdominal pain. During the year prior to admission she had lost 20 pounds in weight and had noted increasing fatigability and loss of appetite.

Physical Examination. Temperature, pulse and respirations were normal. The patient appeared somewhat emaciated and slightly icteric.

The examination of the chest was essentially negative. The left lobe of the liver was palpable and slightly tender.

Laboratory Findings. Urinalysis showed presence of bile; otherwise, negative. Red blood count 4,900,000; hemoglobin 100 per cent; white blood count 15,000, with 75 per cent polymorphonuclear cells with a moderate left shift. Icteric index 50 per cent; van den Bergh test 6.4 mg. per 100 cc. Stools were negative for occult blood, positive for bile.

Roentgen Findings. On December 8, 1939, the gastrointestinal tract was examined and except for diverticulosis in the sigmoid colon no pathological condition was noted. The gallbladder was studied with oral dye and no function was noted. Chest examination on December 13 showed evenly distributed soft infiltrates throughout both lung fields varying from pinhead size to pea size. The distribution was that of a hematogenous spread.

Course. The patient remained in the hospital until December 23, 1939, at which time she was discharged, condition the same as on admission. The patient remained at home until March 8, 1940, at which time she was re-admitted to the hospital. During her stay at home her jaundice had become increasingly intense and she had had continuous pain in the left costovertebral angle. She had also noted increasing weakness. During the week previous to admission, nausea and vomiting had become prominent symptoms. Physical examination at this time showed marked increase in her degree of jaundice. Chest showed some dullness in the right base and numerous fine râles throughout the right chest. The abdomen was distended and physical findings of free fluid in the abdomen were demonstrable. The patient was markedly tender in the left flank and in the left costovertebral angle. She showed pitting edema of both feet and ankles.

Fig. 1. Case I. Roentgenogram of the chest.

Laboratory Findings at Second Examination. Urinalysis showed two plus albumin; positive for bile. Red blood count 3,000,000; hemoglobin 79 per cent; white blood count 34,000, with 93 per cent polymorphonuclear cells with a rather marked left shift. Icteric index 100 per cent plus; van den Bergh test 11.2 mg. per 100 cc. Stools showed four plus occult blood on all occasions.

The patient's course in the hospital was progressively retrogressive and she died on March 16, 1940.

Pertinent Autopsy Findings: Prosector—Dr. Kenneth Olsen. Primary cancer of the gallbladder with direct extension to the liver and diffuse metastases throughout the liver. Diffuse interstitial fibrosis of the pancreas. Diffuse evenly distributed pea-sized metastases were noted throughout all lobes of the lungs.

Pathological Diagnosis. Primary cancer of the gallbladder with direct extension to the liver

and with diffuse metastases to the liver and lungs.

Case ii. D. R., female, white, unmarried, aged thirty-nine, admitted to the hospital on September 11, 1941. The patient had been previously admitted in December, 1935, with an acute nonspecific ulcerative colitis. She had a second admission in June, 1939, at which time a pseudomucinous cystoma of the right ovary was removed. One month prior to this admission the patient developed periodic attacks of generalized cramp-like abdominal pain which gradually increased in severity. Associated with this was increasing anorexia and constipation. During this month the patient lost 15 pounds in weight. For the four days before admission the patient had had repeated emesis.

Physical Examination. Temperature 99° F.; pulse 96; respirations 20. The patient did not appear acutely ill nor did she show evidence of marked weight loss. The abdomen revealed a well healed midline scar. There was moderate generalized abdominal tenderness. No physical findings were noted in the chest.

Laboratory Findings. Urinalysis showed a trace of albumin on several occasions. Red blood count 5,570,000; hemoglobin 91 per cent; white blood count 10,750; differential count showed a slight left shift. Glucose, urea, albumin, globulin, phosphorus and calcium normal. Icteric index and van den Bergh normal. Phosphatase normal. Sedimentation rate 23 mm. corrected. Gastric analysis showed free HCl present; no acid-fast bacilli after concentration. Stools were negative for occult blood.

Roentgen Studies. Flat roentgenogram of the abdomen did not reveal any abnormalities. Gastrointestinal tract was studied completely but there were no abnormal findings. Genitourinary tract was studied by retrograde pyelography which appeared normal. There was practically no visualization of the gallbladder by oral cholecystography. No stone shadows were discernible. The most remarkable findings were in the chest which on September 16, 1941, showed evenly distributed small mottled densities throughout both lung fields. They varied from pin-head size to pea size. Some areas tended toward confluency. The appearance was that of a blood stream spread of an infiltrative process to the pulmonary tissue. Inpression: Miliary carcinosis.

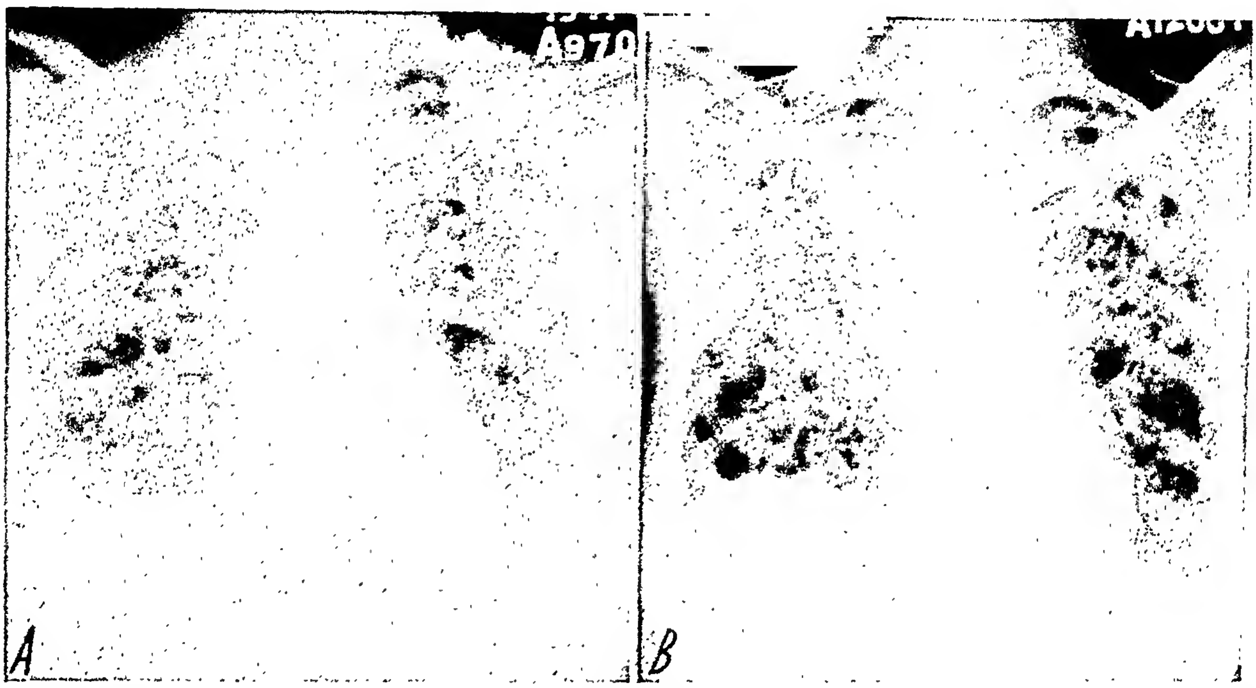

Fig. 2. Case ii. *A*, roentgenogram of the chest taken September 16, 1941. *B*, roentgenogram taken on November 28, 1941. Comparison of these two roentgenograms shows the progress of the lesions and their tendency toward confluency.

A roentgenogram of the chest on October 6, 1941, was similar to the previous examination except for progress in size of lesions and more confluency. Chest roentgenogram on November 28, 1941, showed further progress of chest lesions.

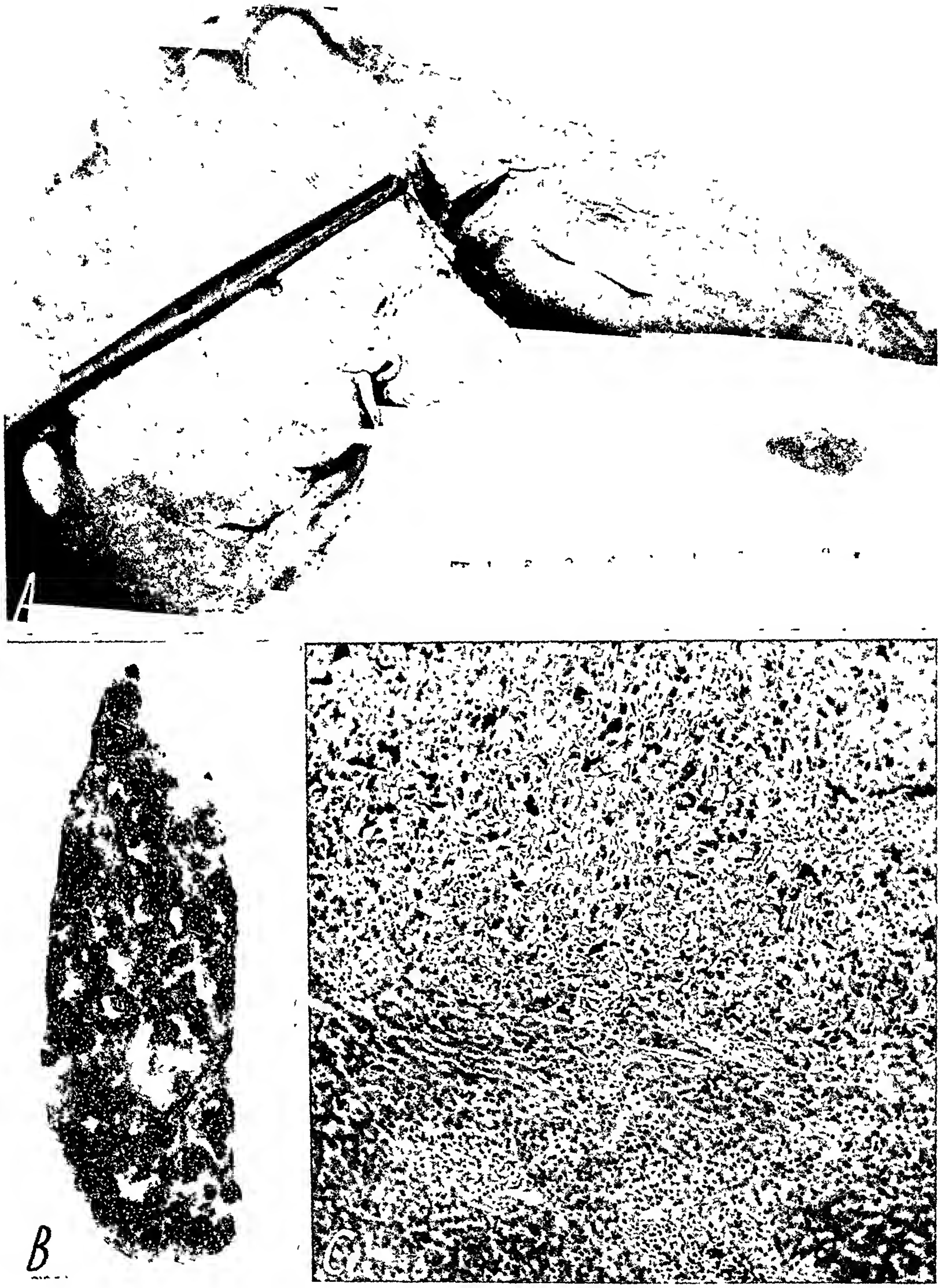

Fig. 3. Case II. *A*, cut section of liver showing massive involvement with metastatic tumor. Clamp holds vein apart at point of invasion by the new growth. *B*, portion of lung showing the character of the metastatic nodules. Several exhibit central necrosis. *C*, photomicrograph of section of lung.

Operation. October 10, 1941. Exploratory laparotomy—high right rectus incision. Firm carcinomatous mass was felt in the region of the gallbladder neck and cystic duct. A large gallbladder was opened and a large amount of thick mucopurulent exudate was removed. Biopsy was taken from the region of the cystic duct. The gallbladder was drained.

Course. Following surgery the patient's wound healed well. However, her course was progressively retrogressive and she died on December 29, 1941.

Pertinent Autopsy Findings. Prosector—Dr. Everett Wesp. Primary adenocarcinoma of the gallbladder with extension to the liver, common and cystic ducts and the peritoneum. The liver was enlarged and contained many cherry to plum-sized metastatic nodules and one huge conglomerate metastasis in the superior portion of the right lobe. This huge nodule showed central necrosis and definite invasion into the veins.

All lobes of the lungs had an almost solid infiltration of innumerable pea to bean-sized metastatic nodules, some showing central necrosis. The nodules contained a large amount of stringy mucoid material similar to that noted in the primary tumor. The tracheobronchial lymph nodes did not show metastases.

Case III. B. T., male, white, aged forty-five, admitted to the hospital on December 1, 1941. For seven years prior to admission the patient had had a very suggestive peptic ulcer history with several instances of hematemesis. He had been in the hospital in November, 1940, following a rather severe gastric hemorrhage at which time a roentgen diagnosis of benign ulceration high on the posterior wall was made. The chest was roentgenoscoped during this same examination and no gross abnormalities were noted. Ulcer therapy was instituted and after a period of about one month the patient was discharged from the hospital with condition markedly improved. Red blood count and hemoglobin were at normal levels at the time of discharge. The patient was symptom free at discharge and until two months prior to his last admission when he developed anorexia and a feeling of fullness in the epigastrium. Food and alkalies were only of slight value in the relief of symptoms. A few weeks after return of abdominal complaints the patient began to experience dyspnea associated with paroxysms of coughing, both of which symptoms had progressed up to the time of admission. He had lost 20 pounds in weight during this same period.

Physical Examination. Temperature 98° F; pulse 90; respirations 22. The patient showed moderate dyspnea even while at rest in bed. His chest showed a few crepitant râles in both bases. There was one small hard supraclavicular node on the left side which clinically was thought to be a Virchow's node. Otherwise, the physical examination was essentially negative.

Laboratory Findings. Red blood count and white blood count were within normal limits. Wassermann reaction was negative. Blood glucose, albumin and globulin were within normal limits. Blood calcium and phophorus were within normal limits. Blood phosphatase was not elevated. Sedimentation rate was 26 mm. corrected. Sputum examinations were negative for tubercle bacilli.

Roentgen Findings. Roentgen examination of the chest on December 16, 1941, showed diffuse infiltrative areas throughout both lung fields which appeared as a hematogenous distribution. These areas tended to become confluent near the hilar shadows and in the mid portions of the lung fields. The roentgen interpretation was miliary carcinosis. The stomach was examined two days later and showed almost complete obstruction at the mid portion of the stomach due to filling in of the lumen with what was obviously an extensive malignant process in the mid portion of the stomach. The extent of the lesion could not be determined due to the degree of obstruction.

Course. The patient's course in the hospital was progressively retrogressive and he died on December 25, 1941. It was impossible to obtain permission for an autopsy on this patient.

Comment. We have included this case as one of miliary carcinosis to the lungs from the stomach although we have no pathological material for confirmation. The roentgen findings in the stomach seem convincing enough for a positive diagnosis of a gastric neoplasm. The roentgenogram of the chest showed an even, diffuse distribution of infiltrative lesions which seemed to be quite typical of metastatic malignancy. The patient at no time during his hospital stay showed any evidence of an infectious process which might account for a miliary type pulmonary lesion. Also we know that one year previously the patient's chest was clear at least at roentgenoscopic observation. Considering the above facts, we think we are

Fig. 4. Case III. *A* and *B*, roentgenograms illustrating the massive involvement of the stomach by new growth. *C*, roentgenogram of the chest.

justified in presenting this case as one of miliary carcinosis to the lungs from the gastrointestinal tract.

Case iv. E. T., male, white, aged sixty-two, admitted to the hospital on February 14, 1943. Three weeks prior to admission the patient developed some personality changes and complained of headache. He became progressively more drowsy and less cooperative and for the two weeks prior to admission was in a semicomatose condition.

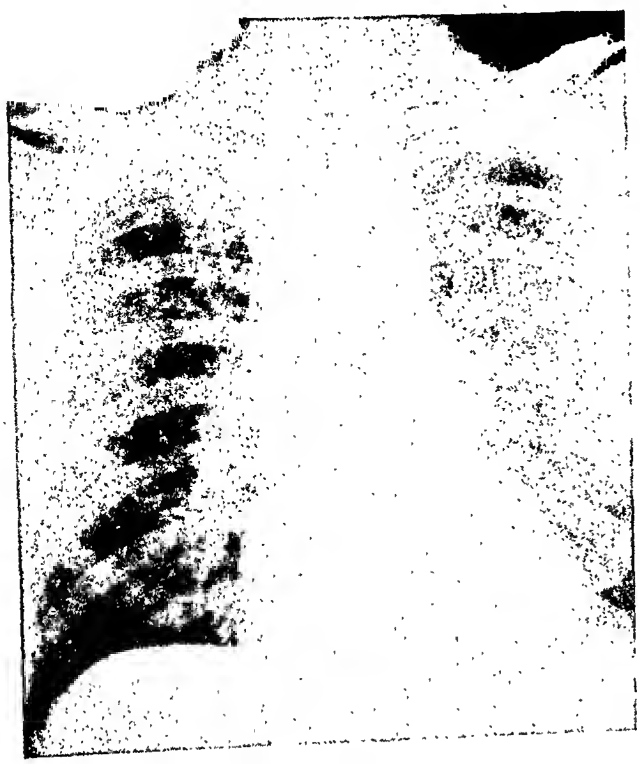

Fig. 5. Case iv. Roentgenogram of the chest.

Physical Examination. Temperature 98° F.; pulse 48; respirations 20. The patient appeared semistuporous and followed directions hesitantly and incorrectly. He was dehydrated and his skin and mucous membranes were pale. Eyes: nystagmus to the left. Chest: some depression of breath sounds throughout the right chest otherwise negative. Neurological: reflexes were hyperactive. There was some motor weakness in the left arm and hand.

Laboratory Findings. Red blood count 3,360,000; hemoglobin 80 per cent; white blood count 16,600; Wassermann reaction negative.

Roentgen Findings. Skull: no abnormalities. Chest: evenly distributed mottled densities were scattered throughout both lung fields. They varied from pin-head to pea size. Their distribution was that of a hematogenous spread. The interpretation was probable miliary carcinosis. Ventriculogram: both lateral ventricles were dilated. The posterior horn of the right was obliterated and the body of the ventricle was depressed. Both right and left lateral ventricles were shifted to the left. The third ventricle was visualized and shifted to the left. The fourth ventricle was not filled. Interpretation: space filling lesion in the right occipitoparietal area. Possible second lesion in the subtentorial region as evidenced by lack of filling of the fourth ventricle.

At operation on February 15, 1943, ventriculography and biopsy of right occipitoparietal tumor were done. Examination of biopsy showed metastatic papillary mucoid carcinoma.

Course. The patient did not regain consciousness following surgery and died five hours later.

Pertinent Autopsy Findings: Prosector—Dr. Kornel Terplan. Primary walnut-sized gelatinous carcinoma of the head of the pancreas with metastatic carcinoma in several mesenteric nodes. Diffuse metastatic carcinoma of both lungs with multiple lentil to pea-sized nodules uniformly distributed through all lobes along with some recent edema and pneumonic congestion. Metastatic carcinoma of all bronchomediastinal nodes. Scattered metastatic nodules throughout the liver. Metastatic carcinoma in the medulla of the right adrenal. Metastatic nodule in the right parieto-occipital area of the brain. Huge metastatic lesion in the right cerebellar hemisphere measuring 5 by 5.5 cm. One hazelnut-sized metastatic nodule in the left cerebellar hemisphere. Extensive metastatic carcinoma of the supraclavicular lymph nodes bilaterally.

DISCUSSION

From a study of the 4 cases reported above, certain points may be stressed which aid materially in making a diagnosis of pulmonary miliary carcinosis. The chest roentgenogram is in many respects quite characteristic:

1. The lesions are evenly and diffusely distributed throughout both lung fields such as we would expect with a hematogenous spread through the pulmonary circulation.

2. The various lesions are not of homogeneous density but appear as soft mottled areas with fuzzy, poorly defined margins.

They usually exhibit a moderate variation in size. The variation may be from a diameter of 1 or 2 millimeters up to over a centimeter. As the disease progresses, there may be some confluency of the lesions.

3. Hilar node involvement from secondary lymphatic spread may or may not be present.

The differential roentgen diagnosis usually involves only two other conditions:

1. *Miliary tuberculosis*—the distribution is the same. However, the lesions are usually more discrete and of a more uniform size. Also the individual lesions have a more homogeneous density. The above, combined with the clinical evidence of infection noted in miliary tuberculosis, usually makes the differential diagnosis relatively easy.

2. *Silicosis*—in silicosis the mid lung fields exhibit the greatest degree of involvement in contradistinction to the even distribution seen in miliary carcinosis. Silicotic nodules appear hard, discrete and of quite uniform size. Also there is usually an associated peribronchial fibrosis and large dense hilar shadows. Secondary emphysema is also apt to be present in silicosis. The history of dust exposure and the clinical course are both helpful in establishing the correct diagnosis.

It is interesting to note the lack of physical findings in the chest in miliary carcinosis. In spite of the extensive pulmonary involvement in some of the cases presented, the positive physical findings were minimal to absent. It may be important to stress this fact as a negative finding. That is, the absence of physical signs in the chest would tend more toward than against a diagnosis of miliary carcinosis in the presence of suggestive roentgen findings.

It is of some interest to comment on the type of spread to the lungs noted in the 4 cases presented. Cases I and II showed primary cancer of the gallbladder with secondary invasion of the liver both by direct extension and by circulatory spread. The subsequent massive pulmonary involvement resulted from invasion of liver veins followed by the release of showers of tumor emboli to the right heart and the pulmonary circulation. These 2 cases are excellent examples of the second method for production of pulmonary miliary carcinosis outlined previously.

Case IV is an example of the first method outlined for production of miliary carcinosis. In this case the primary lesion was in the pancreas with secondary lymphatic spread. Spread to the supraclavicular nodes was probably by the thoracic duct which could also release a shower of tumor emboli to the right heart circulation. The second method of pulmonary spread must also be considered in this case because of the metastatic nodules in the liver. However, there was no pathologic evidence of invasion of the hepatic veins.

The pulmonary involvement in Case III is also probably best explained by spread along the thoracic duct, particularly in view of the presence of a typical Virchow's node. Of course, lack of pathologic data makes it impossible to rule out liver involvement.

Thus in at least 3 of these cases we can trace rather well the pathogenesis of the pulmonary lesions.

CONCLUSIONS

1. Miliary carcinosis of the lungs is not common but when it occurs it is important that the condition be recognized.

2. Certain conditions are necessary for such a spread of cancer since this type of spread must necessarily be hematogeneous through the pulmonary circulation.

3. Four cases have been presented and the pathogenesis of the pulmonary lesions traced.

4. The chest roentgenogram exhibits a fairly typical appearance which has been described.

5. Miliary tuberculosis and silicosis must be considered in the differential diagnosis.

6. The lack of physical findings in spite

of a marked degree of pulmonary involvement has been stressed.

7. A correlation of all available data on a single case will usually make the diagnosis of miliary carcinosis obvious.

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REFERENCES

1. Achard, C., Bariéty, M., Desbuquois, G., and Sternfeld. Granulie cancéreuse des poumons secondaire à un cancer latent de l'estomac. *Bull. et mém. Soc. méd. d. hôp. de Paris*, 1931, *47*, 184–188.

2. Desbuquois, G. Granulie cancéreuse des poumons secondaire à un cancer latent de l'estomac. *Bull. et mém. Soc. méd. d. hôp. de Paris*, 1935, *51*, 1420–1425.

DIAPHRAGMATIC HERNIA AND DILATED ESOPHAGEAL AMPULLA*

THEIR CLINICAL AND DIAGNOSTIC SIGNIFICANCE

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THE number of cases of diaphragmatic hernia and dilated esophageal ampulla diagnosed roentgenologically has markedly increased. From a fraction of 1 per cent seen about two decades ago, we have reached the high figure of over 10 per cent of those cases presented for gastrointestinal roentgenological study. In our last 200 gastrointestinal examinations we encountered 23 cases of either diaphragmatic hernia or dilated esophageal ampulla. This is because the clinician and roentgenologist now routinely look for these conditions during such examinations.

Although the diaphragmatic hernia and the dilated esophageal ampulla are lesions of two different organs of the digestive tract, they have, nevertheless, many similar characteristics. Therefore, a roentgenologic differential diagnosis is at times difficult. For this reason the two subjects are combined in this presentation, describing their similarities and differences.

The most prevalent diaphragmatic hernia is the para-esophageal hiatus type (Fig. 1). The esophageal hiatus is located in the muscular part of the diaphragm and is surrounded by additional fibers derived from the crura of the diaphragm to form a sphincter. The distal end of the esophagus is normally closed at the hiatus by the hiatal sphincter and opens synchronously with deglutition. After middle age the muscles surrounding the esophageal hiatus tend to become atonic producing a dilatation of the hiatus. The increased intra-abdominal pressure resulting from constipation, flatus, pregnancy, etc., causes the fundic portion of the stomach to herniate through this enlarged hiatus, to enter the posterior mediastinum and lie alongside the esophagus, thus forming a para-esophageal hiatus hernia. The distal end of the esophagus is not disturbed by the hernia. It remains attached to the diaphragm.

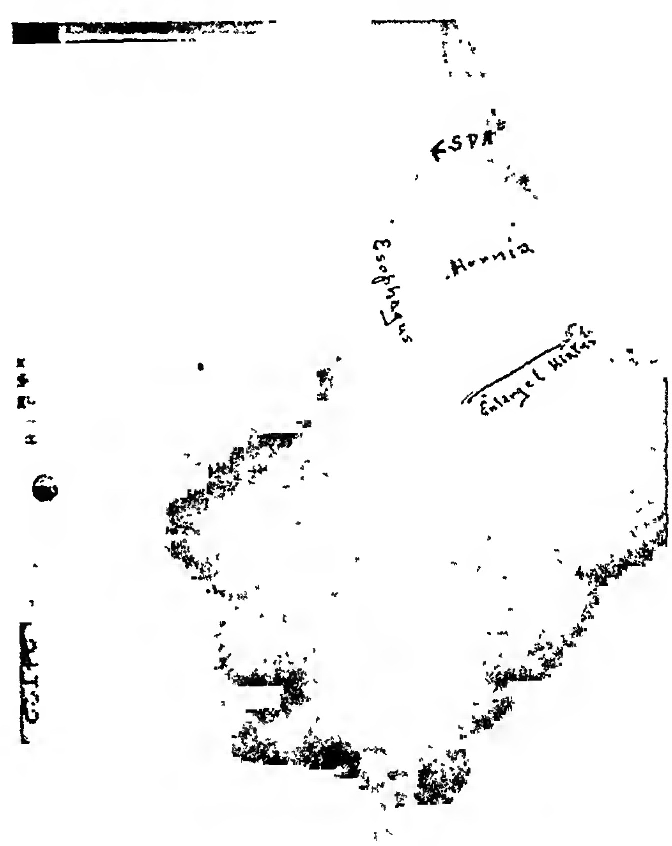

Fig. 1. Para-esophageal hiatus hernia. The esophagus is displaced laterally, and alongside the hernia.

In this position and when dilated, the hernia may produce pressure in the posterior mediastinum simulating symptoms of heart disease, or it may compress the esophagus, producing dysphagia. A very large hernia, by its bulk, can produce dyspnea and also displace the esophagus to the right of the midline. Often a bleeding ulcer is formed at the isthmus between the hernia and the

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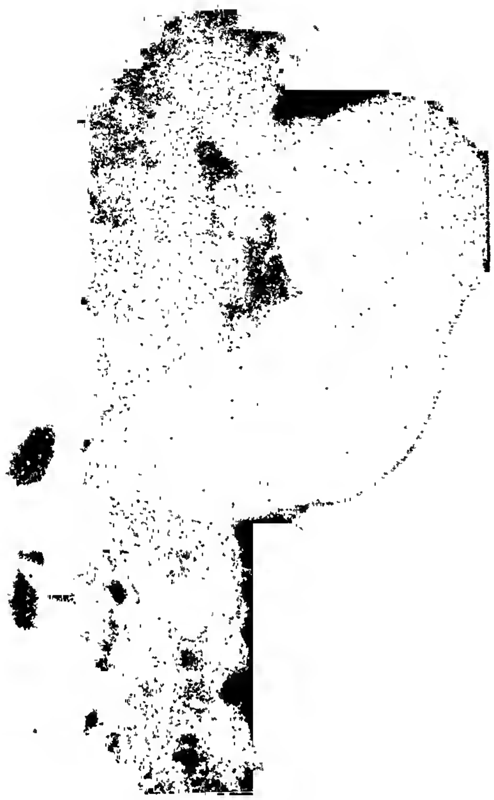

Fig. 2. Para-esophageal diaphragmatic hernia, with a large ulcer at the isthmus between the stomach and the hernia, at the hiatus. This could be mistaken for a diverticulum of the stomach, except that the clinical symptoms were characteristic of a gastric ulcer.

stomach due to the constriction produced by the hiatal sphincter (Fig. 2).

Another type of hiatus hernia is that associated with the upward displacement of the esophagus (Fig. 3). During the protrusion of the stomach through the hiatus it carries the distal part of the esophagus into the mediastinum, freeing it from its attachment to the diaphragm, thus causing it to become tortuous and curved. These curves and tortuosities differentiate this type of hiatus hernia from the congenital, short esophagus type. These hiatus esophageal hernias are operable.

ENLARGED ESOPHAGEAL AMPULLA—PSEUDO-HERNIA

The esophageal ampulla has received little attention in medical textbooks. Mention is made on this subject for the first time in the 1936 edition of Cunningham's Anatomy,[1] as follows:

> Immediately above the level at which the esophagus passes through the diaphragm there is a fusiform expansion of the tube, of variable length and girth, which has been called the ampulla phrenica, or esophageal ampulla. It lies in the lowest part of the posterior mediastinum, where the anterior wall is formed by the sloping posterior part of the diaphragm. Should the esophagus be obstructed at its passage through the diaphragm this ampulla may undergo great distention, and swallowed food may be retained in it and not pass on into the stomach.

Practically all the dilated esophageal ampullae (Fig. 4) that we have observed were due to spasm of the hiatal sphincter or spasm of the esophagus. This dilatation of the ampulla is most likely due to the effort of the esophagus to overcome the spastic obstruction, formed by the hiatal sphincter of the diaphragm. Similar ampullary dilatations in other parts of the gastrointestinal tract are encountered, as, for example, dilatation of the antrum pylorica, when the pyloric ring of the stomach is partly ob-

Fig. 3. Diaphragmatic hernia, with an upward displacement of the esophagus. Note the characteristic tortuosity of the distal end of the esophagus.

structed, or dilatation of the rectal ampulla, when the anal sphincter undergoes obstruction.

On several occasions during roentgenoscopy, formation of the ampulla and spasticity of the esophagus were observed. It was noticed that while the patient was drinking the barium mixture the hiatal sphincter, which normally opens and closes intermittently during deglutition, remained closed longer than usual. The lower 2 inches of the esophagus dilated, forming an ampulla, and an annular contracture formed at the upper end of the ampulla. Spastic ripples appeared around the walls of the ampulla and extended into the tube above it. The annular contracture deepened and finally closed the lumen completely. For a short time the ampulla was closed at both ends. During this time the intra-ampullary pressure increased to such a degree that it overcame the resistance of the hiatal sphincter; the latter opened and the esophageal contents emptied into the stomach, then the esophagus assumed its normal shape. Upon being questioned, the patients stated that the sensation was the same as that experienced during an attack of pain involving a wide area embracing the lower thorax and upper abdomen. Occurrence of such pain makes the patient seek medical aid.

Fig. 4. Enlarged esophageal ampulla. Note the constriction at the distal end of the ampulla, due to spasticity of the esophagus.

DISCUSSION

A dilated ampulla or a hiatus hernia may or may not produce local pain or tenderness. When symptoms are present they are of two types. One is produced directly by the lesion, in which case the usual complaints are dyspnea, prostration, bloating, pressure in the precordial region and shortness of breath. These symptoms are aggravated by a heavy meal or when the patient is in a recumbent position, because the stomach contents then easily regurgitate into the hernia or ampulla. However, when the stomach is partly filled with gas or air, as in aerophagia, the symptoms become aggravated even in the erect posture.

In the second type are symptoms referred to different parts of the body as the external ear, lower jaw, left shoulder and arm, precordium, and occasionally to the region of the gallbladder. The reason for this wide distribution of referred pain becomes obvious upon consideration of the complex nerve supply of the esophagus, diaphragm, and fundus of the stomach. All of these parts are supplied by branches of the upper cervical nerves, the recurrent laryngeal, vagus nerve, the sympathetic nervous system, and the phrenic nerve. We have had patients who were treated for cardiac conditions, chiefly coronary disease, and were confined to bed until a gastrointestinal examination revealed either a diaphragmatic hernia or a dilated ampulla. Harrington[2] states that many of his hernia cases were referred to him with a previous diagnosis of cardiac condition, gallbladder disease or peptic ulcer. Some came to him following surgery which had offered no relief.

The diagnosis of these conditions can be made by roentgenography or esophagoscopy. Either method may fail occasionally

to detect the lesion on primary examination. A second or even a third examination may be necessary to establish the diagnosis. The reason is that the condition is intermittent in character, the hernia often reducing itself, or the spasticity of the ampulla being relieved, freeing the patient from symptoms for days or even weeks. However, when adhesions form and the hernia remains permanently in the mediastinum the symptoms are constant.

TECHNIQUE

The technique for the roentgenographic demonstration of these lesions consists in increasing the intra-abdominal pressure during roentgen-ray exposures. This may be accomplished by placing the patient in supine position and applying direct pressure over the abdomen with an inflated rubber balloon, or by having the patient flex his thighs over his abdomen at the same time raising the shoulders and taking a deep breath.

DIFFERENTIAL DIAGNOSIS

The dilated esophageal ampulla must be differentiated from the following conditions:

1. Diaphragmatic hernia.
2. Cancer of the esophagus or cancer of the pars cardia of the stomach, invading the esophagus by continuity.
3. Cardiospasm.
4. Obstruction due to swallowing of a caustic substance.
5. Diverticula of the esophagus at the cardiac end.
6. Tumors originating in the adjacent organs that invade, or produce pressure on, the esophagus.

The diaphragmatic hernia, especially the para-esophageal type, can be recognized by the fact that it is situated alongside the esophagus above the diaphragm, and both the esophagus and the hernia can be seen separately on the roentgenogram. The ampulla, on the other hand, is in continuation with the esophagus. In the hernia with the upward displaced esophagus, the esophagus enters the hernia at its summit; the distal end of the esophagus assumes a characteristic twist (Fig. 3).

In cancer of the esophagus, a filling defect of the esophagus with an irregular outline, is present.

In cardiospasm, strange as it may seem, there is no spasm in the esophagus or in the hiatus. Cardiospasm is a misnomer. Hurst's[3] conception is that the hiatus is normally closed and is supplied by two sets of nerves: the sympathetic and the vagus. The sympathetic nerves keep the hiatus closed, while the vagus causes it to open. The pathology lies in the inability of the vagus nerve to cause relaxation and opening of the hiatus. He terms it "achalasia"—that is, inability to relax. The distal end of the esophagus in these cases is fusiformly dilated, smooth in outline, with no evidence of spasm. The lumen is uniformly enlarged. The swallowed food accumulates in the esophagus and opens the hiatus by its gravity when the food reaches a certain height in the esophagus. In the dilated esophageal ampulla, on the other hand, spasm is always present either in the ampulla or in the esophagus above it.

SUMMARY AND CONCLUSION

Acquired diaphragmatic hernia and dilatation of the esophageal ampulla are relatively common conditions. They are capable of producing symptoms almost perfectly simulating those produced by grave disease of the thoracic or upper abdominal viscera. Routine search for these conditions during gastrointestinal series will not infrequently give an explanation for the hitherto unexplained complaints. It is also suggested that patients with atypical angina pectoris, particularly if the pain is related to meals, be given the benefit of roentgenologic study before a diagnosis with such a severe prognosis be regarded as established.*

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REFERENCES

1. Cunningham's Textbook of Anatomy. Oxford University Press, New York, [illegible], p. [illegible].
2. Harrington, S. W. Roentgenologic considerations in diagnosis and treatment of diaphragmatic hernia. Am. J. Roentgenol. & Rad. Therapy, 194[illegible], [illegible].
3. Hurst, A. F. Some disorders of the esophagus. J. Am. M. Ass., [illegible].

* [illegible]

CHRONIC NONSPECIFIC REGIONAL ENTERITIS*

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THE YEAR 1932 marks an important landmark in the progress of medical science, for in that year our knowledge of the diseases of the small bowel was greatly advanced as a result of the painstaking work of Crohn, Ginzburg and Oppenheimer.[1] In a paper published in the *Journal of the American Medical Association* these authors described, in its pathological and clinical details, a disease of the terminal ileum affecting young adults chiefly, and characterized by a subacute or chronic necrotizing inflammation, the cause of which was unknown.

Following the above announcement, reports of similar cases began to appear in the literature with ever increasing numbers up to the present day. New facts were discovered about the disease, viz., it was found that the affection is not always limited to the terminal ileum, but may involve any part of the small bowel and at times even the large bowel; it was also found that the lesion was not always continuous but was often interrupted by healthy segments of intestine. Because of the above findings the terms regional or terminal ileitis are gradually giving way to one which is more inclusive, viz., chronic nonspecific regional entertis, which is the title of the present discussion.

Previous to 1932 only a few sporadic cases had been reported, and hardly any before World War I. Was the disease nonexistent before the war or had surgeons and pathologists failed to recognize this affection? It hardly seems reasonable to believe that a disease with such gross manifestations would have failed to attract attention. It is more likely that the disease was very rare before the war for some unexplainable reason. Perhaps the great influenza epidemic then prevalent may have been in some degree a causative factor in bringing about an increase in the incidence of the disease.

The marked increase in this form of enteritis is well illustrated by the following statistical study. Brown and Donald[2] of the Mayo Clinic report that there were only 2 cases in 1922 and no others until 1929. Twenty-four instances of the condition were encountered prior to 1933, and during the past four years there have been 114 patients diagnosed as having this disease entity. Reports by other observers reveal the same tendency, namely, a constant increase in the frequency of the disease.

The pathological manifestations of the disease most often affect the terminal ileum but no part of the small or large bowel is exempt. Several of our cases showed definite involvement of the head of the cecum in addition to the ileum. In 1 case there were several areas of the disease process throughout the course of the colon. In another case extensive involvement of the duodenum was demonstrated four years after resection of the terminal ileum for regional ileitis. The latter case showed internal fistulous tracts extending from the diseased segment into the surrounding tissues.

The pathological process is characterized by a subacute or chronic necrotizing ulceration on a granulomatous basis. This results in a cicatrizing inflammatory process which is sharply localized. The intestinal wall is stiffened, becomes rigid, and the lumen is narrowed, resulting at times in a stenosis with dilatation of the proximal portion of the bowel. If the diseased process is not arrested or removed, perforation may take place with a resulting fistula or abscess formation. Very frequently the diseased segments of the bowel are matted together by

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dense adhesions giving the impression of a tumor in the right lower quadrant of the abdomen. Four of our cases presented large palpable masses which were thought to be due to new growths until their true nature was recognized by operation. The neighboring glands are usually found to be enlarged and the mesentary is edematous.

So far the cause of the disease remains unknown. According to Strömbeck[3] the disease strongly resembles a healed tuberculous ileitis. He is of the opinion that the process may actually be due to a tuberculous infection and advances the following reason, namely, the terminal loop of the ileum is well equipped to combat infection, therefore chances for a tuberculous infection to heal are good. Hence, if healing does occur, a microscopic picture may arise which is identical with that described by Crohn in terminal ileitis. Roentgenologically, Strömbeck believes that chronic terminal ileitis cannot be differentiated from ileocecal tuberculosis. Contrary to the above opinion the great majority of observers are of the opinion that the disease is caused by some other type of infection. One of the main arguments against a tuberculous origin is the rarity with which pulmonary tuberculosis is found associated with regional ileitis while it is very commonly associated with tuberculous ileitis. Not one of our cases showed the slightest evidence of pulmonary tuberculosis.

There are no pathognomonic signs or symptom-complex in regional ileitis which would lead the clinician to arrive at a correct diagnosis, but those which are present are strongly suggestive of an intestinal disturbance. There are abdominal pains which are cramp-like in nature and usually limited to the right lower quadrant. Diarrhea is a frequent symptom with the stools containing mucus and sometimes blood. There is also evidence of a low grade infection, such as loss of weight and strength, fever and occasionally a leukocytosis. On physical examination tenderness is often elicited upon pressure in the right lower quadrant and occasionally a palpable mass may definitely be outlined. Four of our cases exhibited palpable masses in the right lower abdomen.

The diagnosis of the disease can only be established by a thorough investigation of the small bowel. The roentgen method has proved to be the most useful method for this purpose, provided it is carefully carried out. This entails frequent observation of the barium column from the moment it leaves the stomach until it reaches the large bowel, which is then examined by means of a barium enema. When the examination is carried out as above directed the chances are very good of recognizing any organic lesion of the small and large bowel.

The roentgen signs depend upon the gross alterations of the bowel as a result of the pathological changes. In the order of importance and frequency they are as follows:

1. Deformity of the contour of the bowel wall.
2. Narrowing of the lumen of the intestinal tube.
3. Loss of the mucosal pattern.
4. Hour-glass constrictions in the course of the bowel.
5. Rigidity and immobility of the involved segment.
6. Displacement of adjoining segments of the bowel as a result of pressure by pseudo-tumors.
7. Demonstration of internal fistulous tracts.
8. Hypermobility of the intestinal contents.
9. Stenosis with dilatation of the proximal portion of the bowel.

There are several conditions from which chronic nonspecific regional enteritis is to be differentiated.

1. *Chronic Appendicitis.* Most of the cases referred for roentgen examination have a clinial diagnosis of possible chronic appendicitis. Roentgen examination may not establish the diagnosis of chronic appendicitis but it can, at least, exclude regional ileitis. The presence of an appendiceal abscess may be readily diagnosed by

the history of the onset and the absence of intestinal involvement.

2. *Tuberculous Ileitis.* The roentgen appearance of regional ileitis very frequently resembles that of tuberculous ileitis, but the absence of pulmonary tuberculosis, the almost constant accompaniment of the latter, will exclude it.

3. *Colitis.* Colitis is confined to the colon alone. The small bowel is seldom involved, while in regional ileitis the colon is rarely affected without the small bowel also being involved.

4. *Small Bowel Tumors.* Malignant tumors seldom occur in the small bowel, but when they do they are usually localized. In regional ileitis the lesion is more extensive and may present normal bowel segments between the affected areas.

The above discussion is based upon the observation of 12 cases, 2 of which were discovered before 1932. In view of our present knowledge there is no doubt about the nature of the 2 cases, but instead of having called it regional or terminal ileitis it was then described as a chronic inflammatory process, of an undetermined etiology, of the lower end of the ileum.

In view of the fact that even now the exact cause of the affection is not known, the present terminology is little more explicit than the one used at that time.

Case i. D. H., male, aged thirty, was seen in 1926. For over a year he had been troubled with pain in the abdomen, especially in the right lower quadrant. A mild degree of diarrhea was present. The physical examination revealed a well nourished young man with a palpable, tender mass in the right lower abdomen. The clinical diagnosis was chronic appendicitis, but roentgen examination showed a deformed terminal ileum and cecum which was very suggestive of a tuberculous ileitis (Fig. 1), but in the absence of pulmonary tuberculosis such a diagnosis was doubtful.

The patient was operated upon and according to the surgeon's report the lesion did not appear to be tuberculous in nature. The coils of the ileum were thickened and matted together giving the impression of a new growth.

Fig. 1. Case i. Terminal ileum deformed and adherent. Cecum ill defined.

No attempt was made to remove the diseased bowel and the patient died of shock following the operation.

Case ii. R. W., female, aged twenty-five, married, was seen in 1927. For over a year and a half the patient had been troubled with more or less pain in the right lower abdomen. A mild form of diarrhea was present from time to time. Her general health remained fairly good. On physical examination a palpable tender mass was disclosed in the right lower quadrant. The clinical diagnosis was either chronic appendicitis or a new growth. Roentgen examination revealed a distorted terminal ileum with upward displacement of the cecum by the palpable mass (Fig. 2). The general good condition of the patient seemed to preclude a malignant growth, and the absence of pulmonary tuberculosis likewise favored the exclusion of tuberculous ileitis. She was given roentgen treatment and her condition improved, but after a year the symptoms returned and she was operated upon at the Mayo Clinic. A chronic process of the ileum, apparently not of a tuberculous origin and not due to a new growth, was found. Since then she has been operated upon several times for recurrences and at

FIG. 2. Case II. Terminal ileum deformed. Head of cecum displaced upward by palpable mass.

present is, relatively speaking, in fairly good condition.

CASE III. M. A., male, aged sixteen, was seen in January, 1945, because of abdominal cramps, loose watery stools, loss of weight and moderate fever. On physical examination a moderate degree of tenderness was elicited in the right lower abdomen. Roentgen examination revealed a deformed terminal ileum, with narrowing of the lumen and rigidity of the entire segment (Fig. 3). The diagnosis of regional ileitis was confirmed by operation at the Mount Sinai Hospital, New York.

CASE IV. V. C., [illegible] was examined in February, 194[illegible], because of [illegible] [illegible]

because of a sensation of fullness, pain in the abdomen and diarrhea. Another roentgen examination showed a recurrence of the lesion in the segment of the bowel near the anastomosis. The question of another operation was discussed, but neither the patient nor the surgeon was fully in favor of it. At my suggestion it was decided to use roentgen therapy. The reason for this suggestion was based upon the known fact that granulomatous lesions are often radiosensitive, and since this is a case of a granulomatous overgrowth, the possibility that it might favorably be influenced by roentgen irradiation appeared to be a logical conclusion. Therefore, a course of roentgen treatments was given, consisting of ten applications with the following factors: 200 kv., [illegible] mm. Cu plus 1 mm. Al filter, 50 cm. distance, 200 r to each of three fields, front, right side and back. In all he received 2,000 r over a period of twenty days. The symptoms gradually subsided and further roentgen examination showed a definite improvement in the local condition. Recently he was again examined and the lumen of the bowel was found to be definitely wider than before and his present condition is very good.

[illegible]

Case v. J. W., female, aged nineteen, was examined in April, 1940, because of gas pains, loss of weight and strength, diarrhea and a moderate fever. The roentgenogram showed extensive involvement of the ileum and jejunum characterized by loss of the mucosal pattern, irregular contour, marked narrowing of the lumen, and immobility (Fig. 5). The diagnosis of regional ileitis was confirmed by operation at the Mayo Clinic. Notwithstanding the operation, the patient made poor progress and died in May, 1944.

Case vi. F. M., female, aged twenty-one, was referred in 1942 for roentgen examination.

Fig. 5. Case v. Extensive involvement of ileum which is narrow and deformed.

Fig. 4. Case iv. Terminal ileum deformed and fixed.

because of pain in the right lower abdomen, fever and loss of weight. Roentgen examination revealed a deformed terminal ileum with a narrow lumen. The head of the cecum was found to be contracted and irregular in outline (Fig. 6). The diagnosis of terminal ileitis was confirmed by operation at the Jewish Hospital. The patient returned in May, 1943, with a recurrence of the symptoms, and a re-examination revealed involvement of the segment of the bowel near the anastomosis. A second operation was performed but recently she returned with the same complaints and the roentgeno-

Fig. 6. Case vi. Deformed narrow terminal ileum.

Fig. 7. Case vii. Extensive narrowing of the lumen, which is fixed.

gram again revealed a new recurrence of the disease. Roentgen therapy was decided upon. The same factors as previously noted were given with the exception of the dose which was reduced to 100 r because of her small size and debilitated condition. In this case it is too early to draw any definite conclusions; however, six months after treatment she is symptom free and has gained 15 pounds in weight.

Case vii. S. B., female, aged fifty, the oldest patient in the series, was examined in May, 1942, because of pain in the abdomen, especially in the right lower quadrant. There were also nausea, vomiting and moderate fever. Roentgen examination disclosed an extremely narrow, ill defined segment in the region of the ileum which extended across the abdomen and was more or less fixed (Fig. 7). The diagnosis of terminal ileitis was confirmed by operation at the Jewish Hospital. Her present condition is good.

Case viii. M. H., female, aged twenty-one, was referred for roentgen examination of the gastrointestinal tract because of abdominal pain, moderate diarrhea with blood and mucus, loss of weight and strength. The symptoms have lasted about four years with periods of remissions. Of late she has also been troubled with nausea and vomiting. During examination of the stomach and duodenum the proximal jejunum was found to be dilated. This observation led to frequent examinations during the next seven hours. The later observations showed strictures in the bowel with segments presenting deformed contours encroaching upon the lumen of the bowel (Fig. 8). Twenty-four hours later the small bowel was found to be dilated with barium. The colon was filled, but without dilatation. Diagnosis of regional enteritis was confirmed by operation which consisted of an enteroenterostomy. Segments of both the jejunum and ileum were found to be involved.

Case ix. P. F., aged sixteen, was referred in October, 1942, for roentgen examination because of pain, tenderness in the lower abdomen and fever. Three hours after a barium meal the terminal ileum and cecum were partially filled. The ileum was interrupted by strictures with intervening dilated segments. A barium filled

Fig. 8. Case viii. Marked dilatation of segments of jejunum and ileum with intervening strictures.

string-like shadow connected it with the cecum (Fig. 9). On the following day the colon was found to be partially filled. A barium enema showed displacement of the sigmoid flexure to the left, apparently by a mass in the right lower quadrant. The head of the cecum was contracted and irregular in outline probably as a result of involvement by the same disease process. The diagnosis of regional ileitis was confirmed by operation at the Jewish Hospital. The operation consisted in a short-circuiting anastomotic procedure. The patient is now doing well.

Case x. F. W., female, aged twenty-eight, was referred in November, 1942, because of abdominal pain in the right lower quadrant where a tender mass was palpable. Four hours after a barium meal the terminal ileum and proximal portion of the colon were found to be partially filled. The barium in the ileum consisted of small dilated segments due to hour-glass constrictions and the whole was more or less displaced upward apparently by the palpable mass (Fig. 10). On the following day the small bowel was found to be empty and the colon partially filled. Barium enema revealed downward displacement of the sigmoid flexure and compression of the medial margin of the cecum and ascending colon by the palpable mass. The diagnosis of regional ileitis was made and confirmed by operation. The patient returned in July, 1944, with an external fistulous tract. Another operation, which consisted in a short-circuiting anastomosis procedure was performed. Her present condition is good.

Fig. 10. Case x. Hour-glass strictures of terminal ileum.

Fig. 9. Case ix. Narrow terminal ileum with hour-glass strictures.

Case xi. J. I., male, aged twenty-five, was examined in March, 1943, because of abdominal pain, diarrhea and loss of weight and strength. During a period of two years before the present roentgen study the patient was examined in several cities of this country but no definite diagnosis was made to explain the cause of his symptoms. The barium was injected through a Miller-Abbott tube and the ileum was found to consist of many irregular segments, some being dilated while others were more or less constricted and deformed (Fig. 11*A*). On the following day a barium enema revealed marked spasm of the cecum and ascending colon. Within that region a long linear shadow, apparently due to an internal fistulous tract, was recognized (Fig. 11*B*). After the spasm was relaxed and the colon was filled completely, several irregular translucent areas were noted in the cecum, ascending and transverse colon encroaching upon the lumen of the bowel and apparently due to masses of granulomatous infiltrations (Fig. 11*C*). The patient was operated upon and a good deal of the ileum and colon was resected. The diagnosis of a chronic non-

B

Fig. 11. Case xi. *A*, deformed segments of ileum. *B*, spasm of cecum and ascending colon showing a long narrow fistula. *C*, deformed areas in colon proved to be of same nature as the ileitis.

specific enteritis was confirmed. The patient's condition remains good.

Case xii. P. W., male, aged twenty-nine, was referred for an examination in June, 1943, because of pain in the abdomen, diarrhea and moderate fever. In 1939 the patient had been operated upon at the Jewish Hospital for terminal ileitis and remained well for almost four years. The possibility of a recurrence of the disease in the ileum was naturally suspected, but to everybody's surprise the recurrence was discovered in the duodenum which presented all the characteristic signs of ileitis. The duodenal bulb was found to be dilated, the descending portion was narrow and of an irregular outline and was more or less constricted at the inferior flexure. The mucosal pattern was entirely obliterated. Linear shadows, apparently due to internal fistulous tracts, were noted extending into the surrounding tissue from the duodenum (Fig. 12*A*). In the lateral view the deformity and stricture of the duodenal wall was demonstrable to greater advantage (Fig. 12*B*).

The question of operation was given up and at my suggestion roentgen treatment was used. The technique was similar to that of the other male patient. The symptoms gradually receded, the patient gained weight (35 pounds)

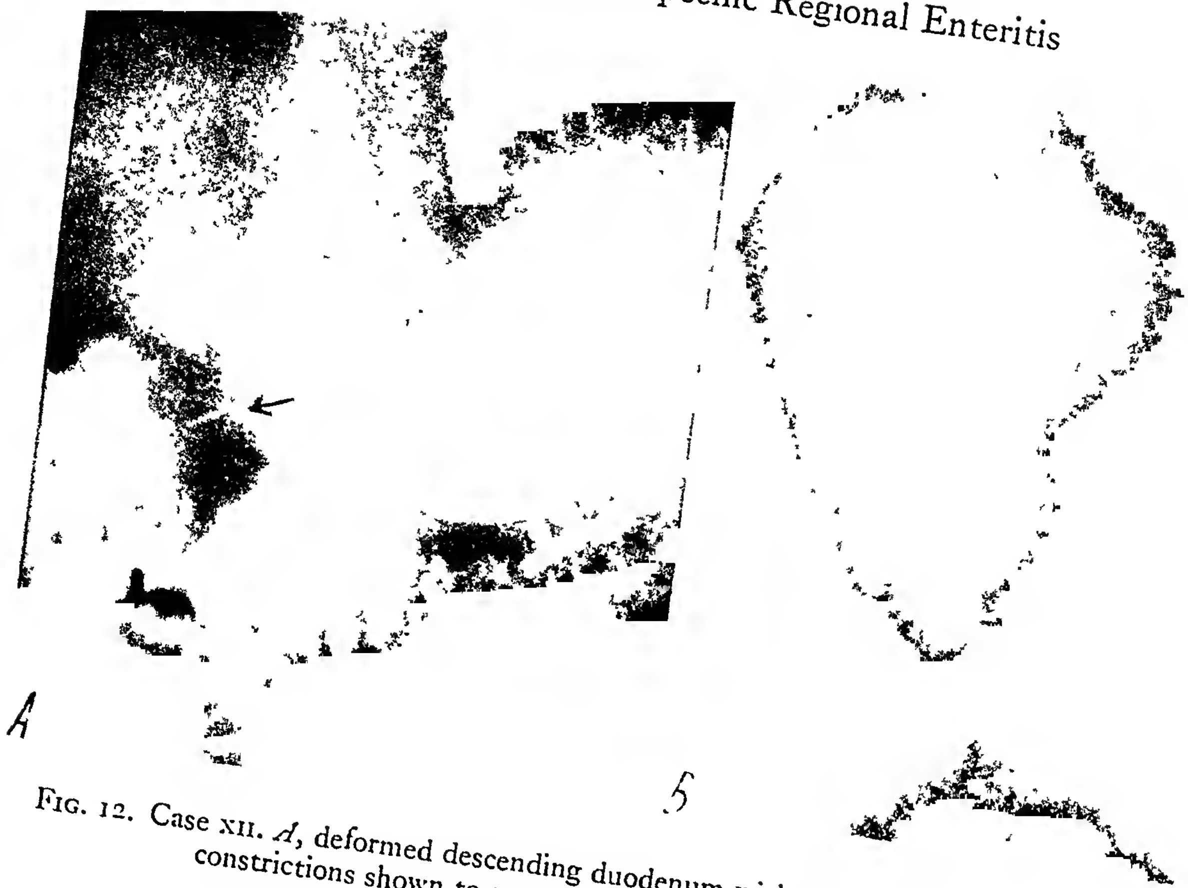

Fig. 12. Case xii. *A*, deformed descending duodenum with fistulae. *B*, lateral view. Duodenal constrictions shown to greater advantage in a case of regional ileitis.

and strength and has now been a full time employee for over a year and a half. Several reexaminations showed the lumen of the duodenum to be less constricted but the mucosal pattern has not fully recovered.

SUMMARY AND CONCLUSIONS

The discussion of chronic nonspecific regional enteritis is based upon the observation of twelve cases, two of which were diagnosed before 1932 which was the year Crohn and his associates reported a series of chronic inflammatory lesions of the terminal ileum.

An analysis of the clinical symptoms and physical signs exhibited by these cases reveal no symptom-complex pathognomonic of the disease. However, they are strongly suggestive of disease of the intestinal tract, a fact of much importance to the roentgenologist who is now taking greater pains in the examination of the small intestine.

Most of the lesions encountered were in the terminal ileum, but some cases showed involvement of the jejunum and duodenum. The cecum was frequently found to be involved and in one case the greater part of the colon was extensively affected.

Recurrences are frequent and take place in the segment of the bowel nearest the anastomosis.

The diagnosis in all of the cases was established by roentgen examination and confirmed by operation. The roentgen signs in the order of importance are as follows: contour deformity, narrowing of the lumen, hour-glass constriction, loss of mucosal pattern, rigidity and immobility, internal fistulous tracts, malposition of neighboring intestine, hypermotility and stenosis.

The treatment in all cases was surgical. In three recurrent cases roentgen therapy was tried with remarkable results.

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REFERENCES

1. Crohn, B. B., Ginzburg, L., and Oppenheimer, G. D. Regional ileitis; pathologic and clinical study. *J. Am. M. Ass.*, 1932, *99*, 1323–1329.
2. Brown, P. W., and Donald, C. J., Jr. Prognosis of regional enteritis. *Am. J. Digest. Dis.*, 1942, *9*, 87–91.
3. Strömbeck, J. P. Terminal ileitis and its roentgen picture. *Acta radiol.*, 1941, *22*, 827–833.

DISCUSSION OF PAPERS BY DRS. ABOWITZ AND BROWN

Colonel B. R. Kirklin, M. C. I was rather interested in reading Dr. Abowitz's paper a few days ago to find that he states the incidence of hernia in his experience has been more than 10 per cent of cases examined. In our experience the incidence hasn't been nearly that high, but has been about 1.8 per cent.

One other feature of his paper in which our experience has been a little different is the incidence of para-esophageal hernia. Of the patients with diaphragmatic hernia that have been operated upon, we have found that only one-third had the para-esophageal type. On the true esophageal hernia which carries the esophagus up with it, we have no accurate statistics but it is my opinion that not more than 25 per cent of the hernias that we have seen have been of the para-esophageal type.

I am anxious to emphasize Dr. Abowitz's statement that the diagnosis of esophageal hernia is primarily roentgenologic. I am sure that 95 per cent of the hernias that are diagnosed at the Mayo Clinic are incidental roentgen diagnoses in the course of a routine examination of the stomach; that is, in at least 90 to 95 per cent of the cases, the clinician has not suspected the presence of a hernia.

Another thing that I would like to emphasize is that approximately 18 per cent of the hernias have a history of bleeding.

On the question of dilated esophageal ampulla, I am not just clear about what Dr. Abowitz means by this symptom or condition. It has been my opinion that there is considerable variation in the width of the lower esophagus and the esophageal ampulla in different individuals. Frequently we see what appears to be dilatation of the esophageal ampulla and upon questioning that patient, usually one past middle life, he will admit to being a rather fast eater; that is, he gulps his food rather rapidly. It seems reasonable to me to assume that that might be one of the contributing factors.

I feel that there is much variation in the width of the lower esophagus. Sometimes it is very difficult to differentiate the dilated ampulla from a very small esophageal hiatus hernia where we have just 1 inch or 2 inches of stomach protruding up through the esophageal hiatus.

In his paper, Dr. Brown developed a few points which seem to be worthy of special emphasis.

In the years elapsed since Crohn and his associates first called attention to the benign, non-tuberculous, subacute or chronic necrotizing and cicatrizing inflammatory intestinal process now known variously as regional enteritis or ileitis, hyperplastic ileitis or enteritis, ulcerohyperplastic enteritis and other similar descriptive names, much has been written and said about the disease, and opinions about practically all phases of it except its etiology are now fairly unanimous.

The roentgenologic descriptions seem, however, to have stressed that stage in the pathogenesis of the disease in which the involved portion of intestine is shortened and its lumen more or less markedly narrowed as a result of the thickening of the intestinal walls.

It is true that this is the most frequent roentgenologic manifestation of the disease but it is not the only one. The earlier in its pathogenesis the disease is encountered, the less markedly will contracting (narrowing—shortening) deformities of any kind be manifest.

In the early stages of the disease the lumen may not be perceptibly narrowed, shortening of the involved portion may not be obvious, and the roentgen diagnosis will be based on such evidence as relatively minor changes in the relief pattern of the mucous membrane, a sense of diminished pliability and mobility perceived by the palpating hand during the roentgenoscopic examination, both combined perhaps with a local or general intestinal hypermotility.

The greater the deformity, the more advanced is the disease, and such roentgenologic findings as stenosis with prestenotic intestinal distention, internal fistulae with peri- or para-intestinal abscesses, hour-glass constrictions and the formation of pseudo-tumors, all are to be considered, in my opinion, as evidence of advanced disease.

Dr. Brown has made a very competent analysis of the roentgenologic manifestations of nonspecific regional ileocolitis, and I would like to commend him for it.

We have been recommending surgical treatment in our cases with extirpation of the involved intestine as the ultimate aim. There have been recurrences, and the management of these often becomes a most trying problem. Dr. Brown's success with roentgen therapy in

at least 2 of his cases is interesting and encouraging. I do not know that roentgen therapy has been tried before, but I can think of no reason why it should not be tried, at least in selected cases.

We will all be interested in Dr. Brown's later experiences along these lines.

Dr. Abowitz (closing). The percentage does not seem so high when one considers that the two conditions, diaphragmatic hernia and esophageal ampulla, are grouped together. The reason for this grouping is that, at times, it is difficult to differentiate one condition from the other on the roentgenogram. The clinical symptoms are of little help, as they are almost identical in both cases.

As to the roentgenographic technique, two points must be stressed: (1) the intra-abdominal pressure should be increased during exposure; (2) the filled esophagus, and the hernia or ampulla, should be taken on the same film. This helps in making the correct diagnosis. Without a filled esophagus, it is at times difficult to recognize the type of lesion one is dealing with.

ROENTGEN EXAMINATION IN CONGENITAL INTESTINAL OBSTRUCTIVE DEFECTS IN INFANTS

ITS AID IN PLANNING SUITABLE SURGICAL APPROACH AND PROCEDURES FOR THEIR CORRECTION

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THE incidence of imperforate anus and atresia of the intestine of various types is variously placed at 1:8,000–1:10,000 (Keen[11]), 1:5,246 (Bardeleben[2]), 1:7,477 (Zimindorff[2]) and 1:11,000 (Kermisson[7]), 1:5,000,[8] newborn infants. From January 1, 1923, to December 31, 1944, there were 9,474 living babies born in the hospital of St. Vincent de Paul and De Paul Hospital. Among these only 2 cases of obstructive congenital intestinal anomalies have been recorded. The condition is thus relatively infrequent, but obviously intelligent correction is of utmost importance. The purpose in presenting these cases is (*a*) to emphasize the importance of early examination to determine the site of obstruction, and (*b*) to draw particular attention to important details of roentgen technique, with special reference to imperforation and atresia of the anus and rectum.

The site of obstruction depends upon the stage at which embryological development has become erratic. Briefly stated, the development of the lower intestinal tract is as follows: In the embryo the urinary tract and the lower intestine at first are one cavity. This cavity becomes divided into anterior and posterior portions by the urogenital membrane—the anterior chamber becomes the bladder and the posterior forms the rectum or mesenteron. The mesenteron descends toward the perineum where it meets an infolding epiblast (proctodeum) which becomes the anus. Malformations in this region are due to failure of the urogenital membrane to separate completely the rectum from the bladder or failure of the proctodeum to meet and unite with the mesenteron. Drueck[6] states that the arrest in imperforate anus is usually at the level of the peritoneal reflection; in females it is usually about 2 cm. and in males it is usually about 3 cm. from the perineum. The atresia may thus be complete (imperforation) or fistulous (atresia), and anomalous openings may be present anywhere between the rectum and the urogenital tract.

Keiller,[7] in 1924, appears to have been the first to recognize the value of roentgen examination in these cases. He advised the use of the roentgen ray "if available," and if sufficient gas had formed, but he did not give details of technique or show illustrations. He also appears to be the first to have used barium suspension injected through the colostomy opening to demonstrate the site of obstruction where surgical intervention from above had become necessary because of failure to locate the blind end of the rectum through the perineum. Desmarest and Ebrard,[5] in 1926, gave bismuth by mouth and made anteroposterior and lateral roentgenograms with an opaque object in the anal dimple.

In 1930 Wangensteen and Rice[12] described a method whereby gas contained in the large intestine was used to delineate the blind end of the rectal pouch. They showed that if the baby were suspended head down, the gas would rise to its highest point and that a roentgenogram made with an opaque object in the anal dimple would demonstrate the extent of separation between the blind end of the rectum and the perineum. The surgeon could then determine whether a perineal approach were feasible. Rhodes[10], in 1934, recommended

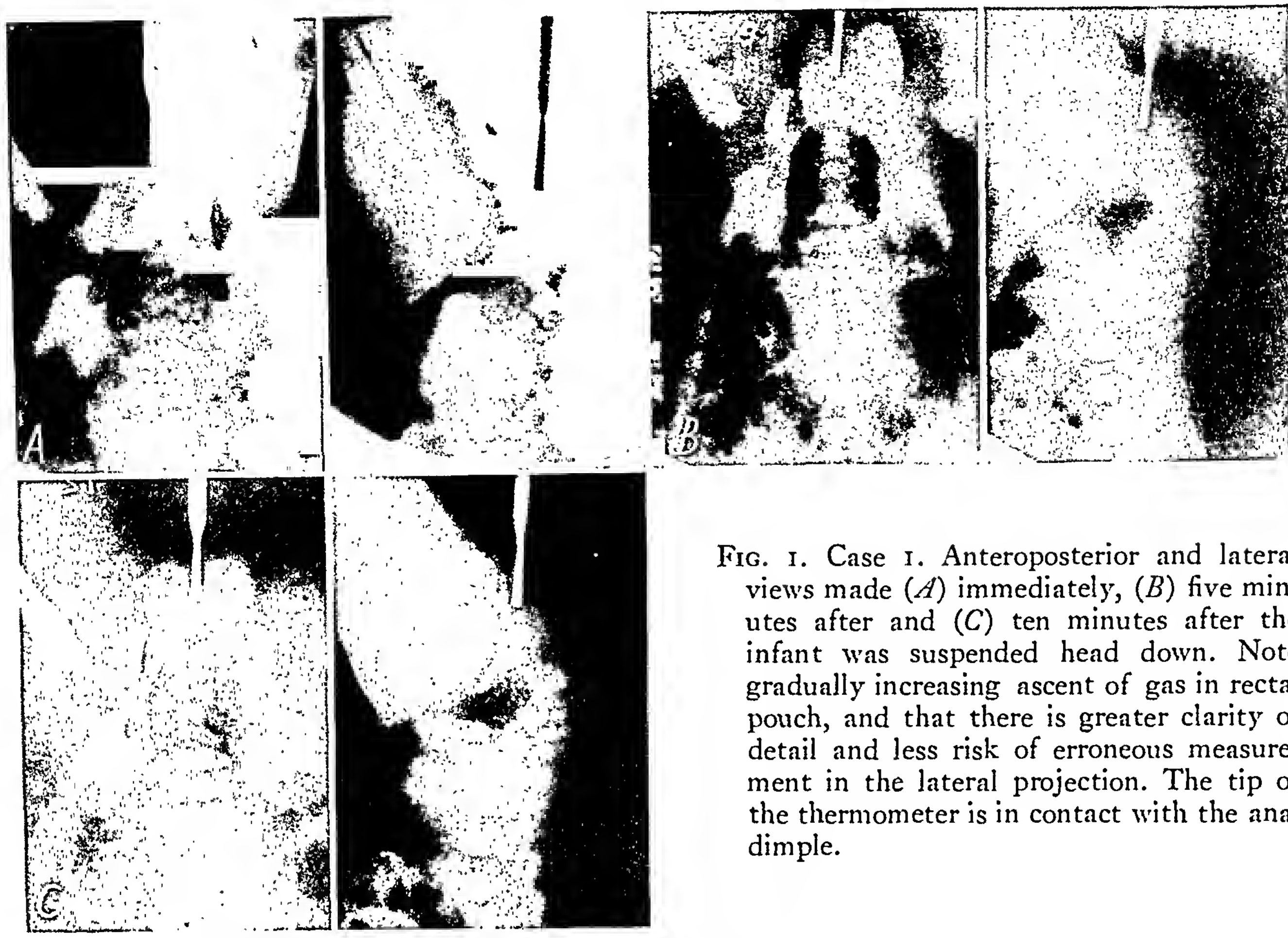

Fig. 1. Case 1. Anteroposterior and lateral views made (*A*) immediately, (*B*) five minutes after and (*C*) ten minutes after the infant was suspended head down. Note gradually increasing ascent of gas in rectal pouch, and that there is greater clarity of detail and less risk of erroneous measurement in the lateral projection. The tip of the thermometer is in contact with the anal dimple.

that the child be stimulated to cry, and buttermilk be given by mouth to obtain filling of the intestine with gas; thereafter, anteroposterior supine and lateral recumbent roentgenograms were made to determine the location of the blind end of the rectal tube.

Ladd and Gross,[8] while recommending the method proposed by Wangensteen and Rice, reported erroneous localization in 2 cases because of insufficient gas in the lower intestine. Berman[1] and Crowell and Dulin[4] drew attention to the possibility of error during the first twenty-four hours of life since gas is not normally present in the colon during the first day. Despite these objections, the method is the simplest devised, and accumulating experience shows it reasonably reliable. The method of Wangensteen and Rice is preferred to those in which the patient remains supine or recumbent since, in the latter, the gas is apt to remain proximal to the blind end of the rectum. Administration of opaque suspension by mouth is likely to cause obstruction of the large intestine.

CASE REPORTS

Case 1. W.E.B., a white male infant, about two months premature, was born after normal home delivery. The birth weight was 5 lb., 10 oz. and the infant appeared to be normal in all respects save that there was no anal orifice, though there was a dimple. He was admitted to the hospital nine hours and twenty minutes after birth. Both parents were healthy and there was no family history of malformations. Three, six and nine hours after admission he was given half an ounce of 5 per cent lactose by mouth for the purpose of obtaining an accumulation of intestinal gas. On one occasion, twenty-seven hours after birth, he vomited green liquid material. The morning following admission, and twenty-seven hours after birth, roentgen examination was undertaken.

Roentgen Examination. The infant was suspended head down before a loaded cassette and exposures were made in anteroposterior and lateral projections, with a thermometer tip held in apposition with the anal dimple. These

roentgenograms (Fig. 1*A*) showed the closed end of the large bowel approximately 2.5 cm. from the tip of the thermometer. It occurred to me that possibly sufficient time had not been allowed to elapse between inverting the baby and taking the roentgenograms. Therefore, two additional sets of roentgenograms were made at intervals of five and ten minutes after the infant had again been suspended head down (Fig. 1, *B* and *C*). It was found in the five minute roentgenogram that the distance between the blind end and the thermometer tip was approximately 1.5 cm., and in the ten minute roentgenogram 1.0 cm. It was further noted that more accurate measurements were possible from the roentgenograms made in lateral projection since, in the anteroposterior views, the pelvic curvature of the intestine gave an erroneously shorter distance.

Operation. Twenty-eight hours after birth an incision was made through the anal dimple and the blind pouch was encountered about 1 cm. above the cutaneous margin. The pouch was isolated, partially freed, and brought down through the opening in the dimple. It was opened and the edges of mucosa were sutured to the skin. No anesthetic was used.

The postoperative course was uneventful and five hours after returning from the operating room the infant had a large meconium stool. He was discharged from hospital the day following operation and since then has shown normal development. Slight anal tightness was overcome by occasional dilatation.

Case II. B., a white male infant, born at term, birth weight 7 lb., 3 oz. The infant was apparently normal except for the fact that the anal orifice was defective; it consisted of a pin-point opening to the left of the median raphe, with no corresponding opening on the right side. A slight amount of meconium was expelled through this orifice twenty and three-quarter hours after birth, but it was not possible to insert a small catheter or the tip of a thermometer through it. There was no vomiting. Twenty-one and one-half hours after birth the infant was referred for roentgen examination. He did not receive any lactose solution to aid in the formation of intestinal gas.

Roentgen Examination. There was a pin-point opening to the left of the median raphe but attempts to introduce the tip of a syringe, a fine catheter and to inject iodized oil were unsuccessful. Roentgenograms made in anteroposterior and lateral projections at intervals up to ten minutes after the baby had been suspended showed the minimum distance between the gas distended rectal pouch and anal orifice to be about 1 cm. In this, as in the previous case, roentgenograms made at earlier intervals showed a greater separation between the gas and cutaneous marker.

Operation. A grooved director was inserted through the pin-point opening and the median raphe was cut. When this was done, the anal canal appeared to be normal except that it was rather small.

The postoperative course was good. The earlier stools were of meconium; later they became normal and the baby was discharged with its mother on the eighth post-partum day.

Comment. These cases demonstrate the importance of waiting a sufficient length of time after inverting the infant before taking roentgenograms. Ten minutes is probably not too long; a shorter length of time is likely to give an erroneous impression. They also illustrate the superiorty of lateral roentgenograms over those made in anteroposterior projection, although both projections should be utilized since the lower end of the rectal canal may be displaced laterally. Contrary to the views of Berman[1] and Crowell and Dulin[4] the time of adequate intestinal gas accumulation cannot be set abitrarily at twenty-four hours since in Case II examination was less than and in Case I only slightly greater than that interval.

Case III. B., female infant, was born, about seven months' gestation, of healthy parents. Her birth weight was 5 lb., 2 oz. She was born at 4:45 A.M. and at 7:00 A.M. there was projectile vomiting of meconium-like material. During the subsequent eighteen hours the vomiting continued. Saline enemas were returned clear, but she could tolerate only about an ounce of solution and they were immediately and forcibly expelled. The fact that a rectal thermometer could be inserted for a distance of only 3 to 4 cm. led to the clinical impression that she had a rectal atresia and she was referred for roentgen examination twenty-eight hours after birth.

Roentgen Examination. The technique of examination was the same as for the cases recorded above. A small catheter was inserted into the anus to a distance of about 3.5 cm., and there appeared to be a rather wide separation between it and the gas-distended rectal pouch in the roentgenograms made ten minutes after the infant had been suspended head down (Fig. 2*A*). This suggested the possibility of a high imperforation of the rectum. For the purpose of more accurately defining the respective blind ends, approximately 15 cc. of air was injected by syringe through the catheter. Contrary to expectation, no gas escaped from the anus and in roentgenograms immediately afterward, the rectum, sigmoid and large intestine could be defined (Fig. 2*B*). Thereafter injection of 15 cc. of iodized oil showed clearly that there was no atresia of the large bowel below the region of the left upper quadrant (Fig. 2*C*). There was slight filling of what was taken to be the distal half of the transverse colon, though it was displaced laterally by a large cystic mass medial to it. The descending portion of the colon had a redundant loop and it was thought that there had been a failure of descent of the cecum. There was a slight accumulation of gas in the small bowel. The following morning the infant was examined again by plain roentgenograms without additional contrast medium (Fig. 2*D*). The large intestine was visualized by gas content in the right upper quadrant and it ended in close proximity to the cyst-like mass. Both the blind end of the intestine and the cyst had been displaced, between the times of examination, from the left to the right upper quadrant. At this time it was also noted that there was marked gaseous distention of the stomach and loops of small intestine. On the basis of these findings it was thought that there was an obstruction of the small intestine, probably in the region of the terminal ileum.

The infant's condition gradually became worse and was very poor when operation was undertaken on the same day as the second roentgen examination. The roentgen impression was confirmed; there was a blind termination of the ileum several centimeters from the proximal end of the colon, and they were joined by a fibrous band. The closed end of the colon was found under the liver but more extensive exploration with reference to the cyst-like mass was not possible because of the infant's poor condition. She did badly after operation and died about sixty hours after birth.

Fig. 2. Case iii. The findings in (*A*), reproduced from a roentgenogram made ten minutes after the infant was suspended head down, show evidence suggestive of high rectal imperforation. This was disproved by insufflation of air (*B*) and injection of iodized oil (*C*). The partially calcified enterocyst is seen in (*C*) and (*D*) in close proximity to the mobile proximal end of the colon.

Autopsy. At autopsy the cyst-like mass seen in the roentgen studies was found to be a partially calcified enterocyst below the hepatic fissure. It contained brownish material resembling fecal matter, and was connected to the terminal ileum by a fibrous strand and to the mid-ileum by an almost atretic loop. Bands of fibrous adhesions connected it to both right and left lobes of the liver and to the

omentum. The ileostomy was wide open and there was no obstruction between it and the proximal small intestine and stomach.

Comment. It appeared feasible to demonstrate the depth of the anal or rectal atresia, using insufflation of air in the anal pouch as contrast medium. The injected air was successful in ruling out the presence of obstruction of the anal canal, rectum and large intestine; this was confirmed by use of opaque medium. An impression of small, rather than large, intestinal obstruction was confirmed at operation. The enterocyst and proximal end of the large intestine were apparently freely movable since between examinations they changed from the left to the right side. This case illustrates the importance of using contrast medium to demonstrate accurately the depth of the anal pouch.

SUMMARY

1. Three cases illustrating congenital obstructing anomalies of the intestinal tract in newborn infants have been presented and details of the technique of roentgen examination have been described. It is believed that proper roentgen examination can be of great aid in guiding the surgical approach.

2. Roentgen examination, to be of value, should be made after the infant has been suspended for at least five, and preferably ten minutes head down, in order to obtain maximum ascent of gas in the blind rectal pouch.

3. Where there is no anal opening, an opaque object should be held in apposition to the site of the dimple. If there is an anal pouch, opaque medium should be injected into it. These measures will permit an accurate estimate of the depth of tissue between the anal membrane or perineal surface and the blind end of the rectal pouch.

4. Roentgenograms made with the patient suspended head down in lateral projection are of greater value in estimating the thickness of tissue between the rectal pouch and the perineal skin surface, since the pelvic curve of the intestine gives an erroneously short distance between these points when viewed only in anteroposterior projection. However, the anteroposterior view is important to demonstrate possible deviation to left or right of the terminal end of the rectum.

The author desires to acknowledge his indebtedness to Drs. E. D. Floyd, N. F. Mullen and B. Steingold, attending physicians, and to Dr. C. C. Smith who operated upon all three patients, for permission to use these cases.

REFERENCES

1. Berman, J. K. Congenital anomalies of rectum and anus. *Surg., Gynec. & Obst.*, 1938, *66*, 11–22.
2. Bragagnola, G. Su di un caso di atresia anorettale congenito complicata a fistola con sbocco nell'utero. *Gazz. d. osp.*, 1939, *60*, 418–425.
3. Cochrane, W. J., and Saunders, R. L. de C. H. Rare anomaly of penis associated with imperforate anus. *J. Urol.*, 1942, *47*, 810–817.
4. Crowell, E. A., and Dulin, J. W. Congenital anomalies of anus and rectum. *Surgery*, 1940, *7*, 529–539.
5. Desmarest, E., and Ebrard, D. Treatment of imperforate anus. *Arch. de méd. d. enf.*, 1926, *29*, 96–101.
6. Drueck, C. J. Malformations of anus and rectum. *Internat. Clin.*, 1925, *1*, 181–197
7. Keiller, V. H. Imperforate anus with report of three cases. *Texas State M. J.*, 1924, *20*, 278–282.
8. Ladd, W. E., and Gross, R. E. Congenital malformations of anus and rectum. *Am. J. Surg.*, 1934, *23*, 167–183.
9. McCready, I. A. J. Two cases of imperforate anus. *Brit. M. J.*, 1944, *1*, 290.
10. Rhodes, R. L. Imperforate anus; suggested mode of handling. *Am. J. Surg.*, 1934, *24*, 828–831.
11. Walters, P. R. Congenital absence of lower portion of rectum and anus. *California & West. Med.*, 1926, *25*, 217–218.
12. Wangensteen, O. H., and Rice, C. O. Imperforate anus; method of determining surgical approach. *Ann. Surg.*, 1930, *92*, 77–81.

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THE SO-CALLED FIFTH AND SIXTH CEREBRAL VENTRICLE*

A CLINICAL AND ROENTGENOGRAPHIC STUDY AND CASE REPORT

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INTRODUCTION

THE correct diagnosis of some of the less frequently occurring cerebral lesions was greatly facilitated and, in many instances, made possible for the first time by Dandy's[1,2] discovery of ventriculography and pneumo-encephalography in 1918 and 1919. Prior to that time, most of these disorders were recognized mainly during postmortem examinations.

To these rare conditions of the central nervous system belong the rather heterogeneous group of true cysts. They should be distinguished from the large division of cyst-like formations or false cysts which arise from various causes as from parasitic maladies, degenerative changes in tumors or tumor-like granulomatous disease processes, interference with the flow of blood through the cerebral vessels, traumatic effects, and other obvious reasons. Sometimes, differentiation may be very difficult as, for example, in those cases where ependymal adhesions snare off portions of the ventricles, converting them into cyst-like structures. Very often, microscopic examination of the walls of the cysts is necessary to differentiate between true and false cysts.

Among the interesting anomalies of development of the region of the septum pellucidum, the corpus callosum and the fornix, rather frequent sites of malformation as described by Jaeger and Bannwarth,[8] Reeves,[11] Love, Camp and Eaton,[10] and Thompson,[13] are the cysts which are caused by the pathological enlargement of the slit between the laminae of the septum pellucidum and the space between the undersurface of the corpus callosum and the psalterium or lyre of David underneath, both perhaps better known as the fifth and sixth ventricle. The knowledge of this subject is by no means new, only the recognition during life is of recent origin. The cavum of the septum pellucidum has been known to anatomists for at least two centuries. Regarding the sixth ventricle, Andrea Verga, an Italian anatomist of the nineteenth century, claimed to be the first to describe this anomaly. Since then it has been called Verga's ventricle or cyst of Verga, although it is sometimes also known as the ventricle of Strambio, the ventricle of the fornix and the triangular ventricle. In 1931, Dandy[3] first evaluated the ventriculographic appearance and clinical symptomatology of these anomalies. To him should also go the honor for the first surgical attempt based upon a correct clinical diagnosis. The proper diagnosis is of importance because of the fair possibility of surgical correction in favorable instances, and because the recognition and separation of the asymptomatic types may avoid unnecessary surgical procedures.

ANATOMY

In most textbooks of anatomy, the cavum of the septum pellucidum and the cavum of Verga are mentioned only briefly, the former more extensively discussed than the latter, and the same is true in textbooks of pathology, regarding their hydropic alteration. However, it would be erroneous to conclude from this that they are extremely rare. According to Dyke[5] these developmental anomalies occur singly

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or in combination once in every three hundred persons.

The cavum of the septum pellucidum is usually referred to as a cystic or hydropic enlargement of the potential space between the leaves of the septum pellucidum which, lying in close apposition, but none the less being separated from each other, form the medial partition of each anterior horn and

Fig. 1. A coronal section of the brain through the region of the cerebral peduncles, showing a cavum of Verga. The tip of the probe points to one distinctly visible wall.

Fig. 2. A frontal coronal section of the same brain, showing a co-existing cavum of the septum pellucidum. The tip of the probe enters the lower portion of this cavum.

adjacent portion of the body of the lateral ventricle, and simultaneously the lateral boundary of the fifth ventricle. The anterior wall consists of the undersurface of the genu and the adjoining part of the corpus callosum. The posterior boundary is formed by the anterolateral surface of the columns of the fornix, the floor by the anterior commissure and the rostrum of the corpus callosum, while the roof is produced by the frontal portion of the body of the same structure. The cavum lies in the median sagittal plane, its main axis having a vertical direction.

Caudally to the cavum of the septum pellucidum and also approximately in the same plane lies the cyst of Verga occupying the space between the undersurface of the corpus callosum and the top of the psalterium, a commissural structure between the rhinencephalic pathways in the fornices. The posterior boundary of this cavum is contributed by the bulge of the splenium of the corpus callosum, and the anterior wall is formed by the limbs of the fornix. The structure has a triangular shape and flares out to either side, following for a short distance the curved course of the fornices (Fig. 1 and 2).

Dandy[3] states that both ventricles coexist and, in most instances, also coalesce, both cysts appearing as one large cavity. The point of coalescence is occasionally conspicuous by a more or less marked narrowing or actual constriction that bears resemblance to an aqueduct-like structure. These communicating cysts are frequently associated with developmental anomalies of the fornices. The cavum of Verga may exist on one side of the midline only; the other alluded half may be absent or a potential space.

The fifth and sixth ventricle may be completely isolated from the surrounding regular ventricular system, constituting a closed type of cystic enlargement. However, this occurrence is infrequent, for they are usually connected through various openings with the third and lateral ventricle. These openings are inconstant in location, shape and size, very often being subdivided by threads of tissue. The most frequently encountered names for them are the foramen of Mihalkowski and the valve of Vieussens.

Dandy[3] advises against the use of the term ventricle because their embryological development is entirely independent and also different from the anlage of the

regular ventricular system. According to Hochstetter,[6] a process of absorption within the originally solid leaf of the septum pellucidum is supposed to convert this structure into two parallel laminae with either a potential or cystic space between them. In contrast to it is the origin of the regular ventricular system which arises from the original neural tube by a process of evagination. Dandy[3] also points to the fact that the so-called fifth and sixth ventricle are conspicuous by the complete absence of choroid plexus in their wall.

PHYSIOLOGY

Being considered as developmental anomalies, no physiological importance is attached to their existence. However, a great deal of study has been devoted to the origin of the fluid in these cysts. It is obvious that the instances with communication into the regular ventricular system contain cerebrospinal fluid. In cases without any communication, the mode and site of production of the fluid is without satisfactory explanation, and, so far, only theoretical speculations have been offered instead. Some authors were of the view that a transudate from the third or lateral ventricle constituted the main source of the fluid. Van Wagenen and Aird[14] objected, basing their argument against it on the sometimes considerable thickness of the wall of these cysts which is incongruous with the suspected mechanism of transudation into the cysts. Wolf and Bamford[15] tried to find ependymal cells in the lining of the cysts as a plausible source. However, they and other authors alike did not find such cells in the wall, it being composed mainly of glial fibers with a moderate number of interlaced fibrillary astrocytes. None the less, they admitted that the presence of aberrant or greatly modified ependymal cells with secretory properties could not definitely be ruled out.

It is also rather surprising that there is no adequate chemical analysis. In his report on the chemical analysis of the contents of 56 cerebral cysts, Stern[12] did not mention even one of the congenital type. The explanation for this may perhaps be found in the technical difficulties which are encountered during the surgical exposure since, as a rule, blood is mixed with the fluid.

PATHOLOGY

Van Wagenen and Aird[14] divide the cysts of the fifth and sixth ventricle into two main groups, the communicating and non-communicating, the latter being subdivided into the primary and acquired variety. This division is based mainly on the observation that the non-communicating type may give rise to clinical symptoms; the other variant remains asymptomatic in most instances.

In the primary non-communicating type, no openings have ever been established since their first embryological appearance. They remain completely isolated from the adjacent regular ventricular system. This group is seemingly extremely rare. According to Dyke, only one case has been observed among 4,000 pneumo-encephalographic examinations. As a rule, the non-communicating cavity changes into a communicating cyst because the steadily growing intracystic pressure causes breaks in the wall with the establishment of fistulous openings into the adjacent third or body of the lateral ventricle. From this type arises the secondary or acquired non-communicating division whenever obliteration of the once produced communication reconstructs the continuity of the wall. This mechanism is mainly the result of changes associated with universal or partial hydrocephalus, causing hydrops of the fifth and sixth ventricle alone or in association with dilatation of the regular ventricular system.

Both variants of the closed type may give rise to clinical syndromes by blocking the outlet of the third ventricle, the foramina of Monro or perhaps both, producing an internal hydrocephalus and increasing the intracranial pressure. These

cysts may also exert direct pressure upon the adjacent solid neural structures, especially the corpus callosum which becomes flattened and atrophied. It is also easily understood how intermittency of the deleterious effect produced by these cysts may ensue, simply by cyclic changes from the non-communicating to the communicating and again back to the closed variety.

The differentiation between the closed and open type is easily made by careful air studies of the intracranial content. If the air appears simultaneously in the cysts and also in the regular ventricular system, this is sufficient proof of free communication. However, careful consideration should be given to the possibility that the alteration of the intracranial pressure, associated with and following the drainage of the cerebrospinal fluid, may have reopened otherwise obliterated fistulae or set in motion a ball valve-like mechanism. In favorable instances, a permanent opening may be established in this manner and a curative effect obtained. In view of these possibilities, it is advisable to repeat the roentgen examination after twenty-four, forty-eight or more hours in order to study the behavior of the air in the cysts in comparison with the regular ventricles. Air may remain trapped within the cysts at a time when the other ventricles have already partially or completely regained their roentgenographic opacity. This is evidence of an unstable communicating system. An associated considerable thickness of the wall may also be contributory to retarded absorption of air.

CLINICAL SIGNS

It has only recently been pointed out that clinical manifestations may be produced by these hydropic anomalous ventricles, especially by the closed type. However, in no reported case was the symptomatology characteristic enough to permit a correct diagnosis with a fair degree of accuracy.

Hitherto published reports revealed the presence of mental and neurological disturbances. The fact that Verga's cases were inmates of psychiatric institutes is perhaps more than just a curious coincidence. However, there are also many descriptions where these cysts have been found during postmortem examinations of mentally and neurologically normal persons.

Neither the mental nor the neurological signs are in any way specific. The neurological syndromes are usually referable to the sequelae of increased intracranial pressure with its well known subjective and objective manifestations. Convulsions have been reported. Should the corpus callosum be sufficiently damaged, the somewhat vague syndrome that is associated with such a location of the lesion may dominate the clinical picture. Even less specific than the neurological symptoms are the mental signs, resembling psychoneurotic features in many instances. Perhaps the intermittency of the clinical signs and also the long duration are worthy of consideration. It is obvious that the differential diagnosis, from a clinical point of view, without the aid of roentgenographic air studies, offers great difficulties.

THE ROENTGENOGRAPHIC APPEARANCE AND ITS DIFERENTIAL DIAGNOSIS

A plain anteroposterior and lateral roentgenogram of the skull will hardly give evidence as to the presence of these cysts because the specific weight of their content does not materially differ from that of the surrounding neural structures and the cerebrospinal fluid, thus affording neither obstacle nor facilitation for the penetration of roentgen rays. Under extraordinary circumstances one may suspect the presence of these cysts on plain roentgenograms if there should show up some incidental calcification of either the wall, content, or perhaps both. On an anteroposterior view of the skull, such calcification may easily be confused with

and can hardly be differentiated from other calcifications in a similar location as, for instance, from calcareous deposits in the pineal gland or in the course of the choroid plexus of the third ventricle, or from partially calcified tumors of the midline. A lateral view offers the same differential diagnostic difficulties. From the foregoing, it may be concluded that only air studies afford sufficient security in the establishment of a correct diagnosis.

Air studies of cases with the closed type of cysts of the cavum pellucidum will reveal on a good anteroposterior roentgenogram a dense, rounded shadow between the air-filled anterior horns and the frontal portion of the body of the lateral ventricles with their gaseous content affording a sharp contrast. This rounded shadow separates the leaves of the septum pellucidum, bulging each one toward the lumen of the anterior horns in a more or less symmetrical way. On the lateral view, this shadow may not become discernible for because of its smallness it is easily extinguished by the subtraction effect of the air in the regular ventricles which, being projected upon each other, reinforce the phenomenon of subtraction. A co-existing Verga's cyst may be diagnosed by its mechanism of displacement which depresses and distorts the roof and body of the third ventricle, and also by the appearance of an internal hydrocephalus, as has been pointed out in the preceding pages. A coincidentally calcified pineal gland may also be displaced downward and posteriorly. In pneumo-encephalographic studies with visualization of the corpus callosum, a thinning of this structure may also appear. Concerning the differential diagnosis, tumors arising from the septum pellucidum or the anterior portion of the falx have to be distinguished from the cysts of the closed type lying between the leaves of the septum pellucidum. Regarding the differential diagnosis of the closed type of the cyst of Verga, tumors of the third ventricle and of the pineal gland closely resemble the roentgenographic appearance of Verga's cavum.

In contrast to the difficulties encountered in recognizing the closed cysts is the ease with which open types are visualized on an anteroposterior roentgenogram. However, this direction alone does not permit the recognition of a co-existing sixth ventricle because they lie in the same plane and are consequently superimposed. Their co-existence is at once discovered on an additional lateral view. Here in turn, a co-existing cavum pellucidum may not show up for the same reason as has been discussed regarding the closed type. The cyst of Verga is easily seen as an oblong shadow of least density, its top usually appearing somewhat below the upper boundary of the nearby ventricular body and its floor slightly lower than the bottom of the same structure. This appearance is based on the anatomical peculiarity of the corpus callosum which, narrowed down to a small fascicle in the midline, lies here nearer the

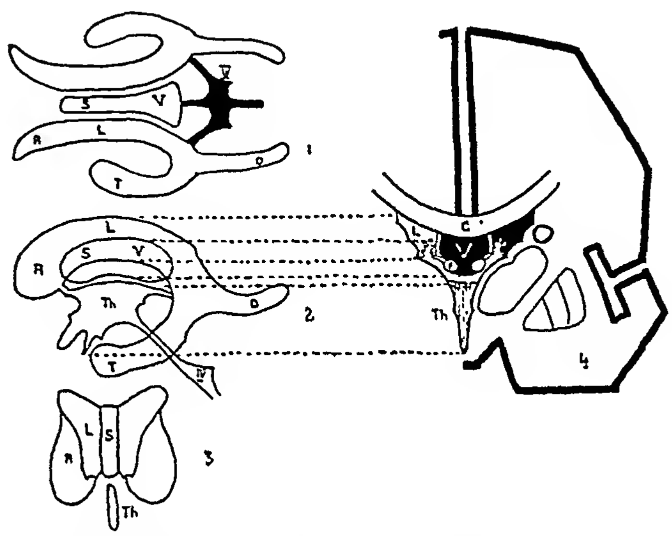

Fig. 3. Schematic drawing demonstrating the topographic relationship of the cyst of the cavum of the septum pellucidum and cavum vergae. *1*, view of the ventricular system from above; *2*, lateral view of the ventricular system; *3*, frontal view of the ventricular system; *4*, coronal section through the brain at about the mid-region of the body of the lateral ventricle; *A*, anterior horns; *C*, corpus callosum; *F*, fornix; *L*, lateral ventricle; *O*, occipital horns; *S*, cyst of cavum of septum pellucidum; *T*, temporal horns; *Th*, third ventricle; *V*, Verga's cyst; *IV*, fourth ventricle.

base of the skull than laterally where it diverges upward forming there the roof of the lateral ventricle. On the other hand, the floor of the cyst of Verga rests upon the psalterium, just above the tela choroidea of the third ventricle and the tectum of the midbrain, these structures being higher compared with the floor of the ventricular body (Fig. 3).

As both cysts co-exist in practically all instances, they cause on the lateral view the appearance of a comma-shaped shadow, with its longest axis oriented in the rostrocaudal direction. This comma-shaped shadow may show a slight constriction near the center, indicating the point of union.

Although the isolated occurrence of a Verga's cyst without the cyst of the cavum pellucidum has been denied by Dandy,[3] this anomaly by itself has also been reported. Leslie[9] observed such an instance and he tried to coordinate his exceptional case with Dandy's statement as to the contrary. Leslie speculated on the possibility that a co-existing cyst of the septum pellucidum was present at an earlier period, but because it became obliterated later, gave the impression of an isolated Verga's cyst in this particular case.

Regarding the differential diagnosis of the roentgen findings in the communicating types, agenesis of the corpus callosum may produce a similar appearance. Hyndman and Penfield[7] studied these cases and gave a detailed description of their roentgenographic appearance. In cases with congenital agenesis of the corpus callosum, the roof of the third ventricle reaches upward to the undersurface of the falx which, in some instances, actually indentates the top of the third ventricle which is also broader than usual. While the third ventricle is extending upward, it comes to lie between the anterior horns and adjacent portions of the lateral ventricles, pushing these structures to either side. Furthermore, the absent corpus callosum causes a batwing-like outline of the lateral ventricles on an anteroposterior view. This and the already mentioned imprint of the roof of the third ventricle by the falx are characteristic enough to permit a differential diagnosis between agenesis of the corpus callosum and communicating hydrops of the cavum pellucidum on an anteroposterior roentgenogram. On a lateral view, the cyst of Verga may be separated from the upward extending third ventricle in congenital agenesis of the corpus callosum by the presence of a line of demarcation which indicates the bottom of the cyst of Verga and the roof of the third ventricle, this demarcation being absent in agenesis of the corpus callosum.

CASE REPORT

Mrs. W. B., housewife, white, aged twenty-five, was admitted to the neurological service of the Jefferson Hospital for the relief of headache and convulsive seizures. Since about her twelfth year of life she had been suffering from this diffuse headache, which came in bouts and was frequently associated with nausea and occasional vomiting. Very often, her headache was accompanied by general aching, and occasionally it occurred without other symptoms. Of late, these episodes of headache appeared closer together and were getting progressively worse. At no time did she ever experience any double vision, motor or sensory impairment. She also complained a great deal of nervousness, inability to concentrate and forgetfulness.

For the last five or six years she had also been suffering from episodes of unconsciousness for which she had no recollection. However, her immediate relatives reported generalized jerking of arms and legs during the state of unconsciousness. They also observed bluish discoloration of the face and adjacent blush zone prior to the onset of the convulsive phenomenon. Tongue biting was also noticed. The patient never lost urine or stool during the convulsions. The convulsive seizures lasted for several minutes and were always initiated by loss of posture and groaning. No abnormal subjective sensation preceded the convulsion. Afterwards, the patient was comatose and later disoriented. This confusion wore off gradually over a period of several hours and severe headache followed. Prior to the onset of

the headaches and convulsive seizures, the patient was healthy. Her family history was also essentially negative and non-contributory.

The physical and neurological examinations were essentially negative. The analysis of blood and urine did not reveal any abnormality. The spinal fluid was clear, colorless and under normal pressure. The chemical, serological and cytological examination of the spinal fluid was negative. Following the spinal puncture, her

Fig. 4. Anteroposterior view of skull with air in the ventricles. Between the anterior horns the two leaves of the septum pellucidum are seen. They enclose a communicating type of cyst of the septum pellucidum.

symptoms became worse; a drawing sensation appeared in the nape of her neck, and she complained of seeing every object "four times," one behind the other one.

In view of the severe headache, a ventriculogram was made and the following roentgen findings were obtained: On the anteroposterior view of the skull (Fig. 4), a cavum pellucidum

Fig. 5. Lateral view of skull with left side away from film. Roentgenogram was taken immediately after trephining for ventriculography. A comma-shaped shadow appears. The arrow points to the junction of the two cysts.

became visible. On the lateral view (Fig. 5 and 6) a cyst of Verga appeared, both anomalies being united and forming an oblong comma-shaped shadow of least density with a slight constriction at the point of coalescence. The diagnosis of a congenital hydrops of the fifth

Fig. 6. Same view but with right side away from film. The comma-shaped shadow is distinctly visible, its bottom being sharply demarcated from the roof of the third ventricle. *Th*, third ventricle.

and sixth ventricle was made. The presence of air in these cysts proved a free communication. Additional air studies were taken at twenty-four, forty-eight and sixty-two hours following the trephining for ventriculography (Fig. 7). From these studies it became clear that the absorption of the air in these cysts was somewhat delayed in comparison with the regular ventricular system. This finding would suggest

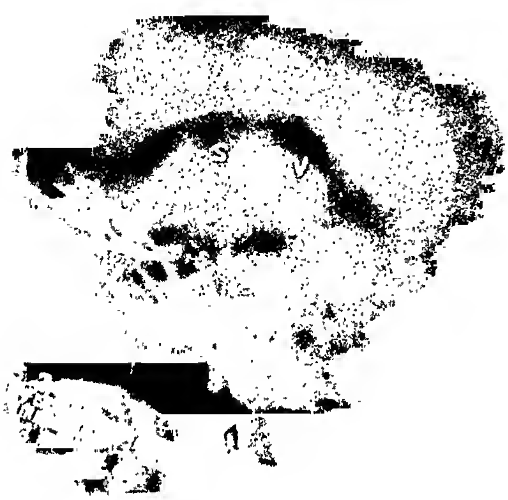

FIG. 7. Lateral view of skull with right side up, taken forty-eight hours following trephining. The air in the ventricles is less than in the still distinctly visible comma-shaped shadow caused by the coalescence of the cyst of the cavum pellucidum and the cyst of Verga. *S*, cyst of septum pellucidum; *V*, cyst of Verga.

faulty communication and also thickened walls of the cysts.

Following this procedure, the patient felt better for several weeks. However, the headache and convulsions returned later in an unabated manner. In view of the fact that the roentgenograms did not give any evidence for blocking of the cerebrospinal pathway, and also on account of the many psychoneurotic features of the case, no surgical attempt was made to correct the existing anomalies.

SUMMARY

The cyst of the cavum of the septum pellucidum and the cyst of Verga are not uncommon developmental anomalies which may occasionally give rise to clinical signs. They are divided into two groups, the communicating and the closed type, the latter being subdivided into the primary and acquired varieties. The closed group is more prone to cause mental and neurological syndromes. A correct diagnosis can be made only with air studies. In the open type, the usually co-existing fifth and sixth ventricles communicate with each other and appear as one long, comma-shaped shadow on the lateral view. The closed type of the cyst of the cavum of the septum pellucidum causes separation and bulging of the leaves of the septum pellucidum toward the lumen of the anterior horns while the closed cyst of Verga produces signs of displacement, often associated with production of internal hydrocephalus. A twenty-four hour, forty-eight hour or even later roentgenogram after the introduction of air into the ventricles should be taken because normally closed types of these cysts may be reopened during the alteration of the intracranial pressure following the drainage of the cerebrospinal fluid. Retention of air in these cysts is suggestive of a ball valve-like mechanism governing the communicating system between these cysts and the regular ventricular system. A fairly typical case is shown and the roentgenographic differential diagnosis is discussed.

REFERENCES

1. DANDY, W. E. Ventriculography following injection of air into cerebral ventricles. *Ann. Surg.*, 1918, *68*, 5. Reprinted in AM. J. ROENTGENOL., 1919, *6*, 26-36.
2. DANDY, W. E. Roentgenography of brain after injection of air into spinal canal. *Ann. Surg.*, 1919, *70*, 397-403.
3. DANDY, W. E. Congenital cerebral cysts of cavum septi pellucidi (fifth ventricle) and cavum vergae (sixth ventricle). *Arch. Neurol. & Psychiat.*, 1931, *25*, 44-66.
4. DAVIDOFF, L. M., and DYKE, C. G. The Normal Encephalogram. Lea & Febiger, Philadelphia, 1937.
5. DYKE, C. G. Diseases of the skull and intracranial contents. In: Diagnostic Roentgenology. Ross Golden, Editor. Thos. Nelson & Sons, New York, 193[illegible].
6. HOCHSTETTER, F. Beiträge zur Entwicklungsgeschichte des menschlichen Gehirns. I. Deuticke, Wien, 1919.

7. Hyndman, O. R., and Penfield, W. Agenesis of corpus callosum; its recognition by ventriculography. *Arch. Neurol. & Psychiat.*, 1937, *37*, 1251–1270.
8. Jaeger, F., and Bannwarth, A. Kongenitale Cysten des Cavum septi pellucidi und Cavum Vergae und ihre operative Behandlung. *Zentralbl. f. Chir.*, 1941, *68*, 1058–1072.
9. Leslie, W. Cyst of cavum vergae. *Canad. M. Ass. J.*, 1940, *43*, 433–435.
10. Love, J. G., Camp, J. D., and Eaton, L. M. Symmetrical cerebral calcification, particularly of basal ganglia, demonstrable roentgenologically, associated with cyst of cavum septi pellucidi and cavum vergae. *Proc. Staff Meet., Mayo Clin.*, 1938, *13*, 225–232.
11. Reeves, D. L. Congenital absence of septum pellucidum. *Bull. Johns Hopkins Hosp.*, 1941, *69*, 61–71.
12. Stern, K. Chemical study on fluids obtained from cerebral cysts; report on 56 cases. *Brain*, 1939, *62*, 88–95.
13. Thompson, I. M. On certain Abnormal Conditions of the Septum Pellucidum. University of California Press, Berkeley, 1932.
14. Van Wagenen, W. P., and Aird, R. B. Dilatations of cavity of septum pellucidum and cavum vergae. *Am. J. Cancer*, 1934, *20*, 539–557.
15. Wolf, A., and Bamford, T. E. Cavum septi pellucidi and cavum vergae. *Bull. Neurol. Inst. New York*, 1935, *4*, 294–309.

BENIGN GIANT CELL TUMOR OF THE SPINE

REPORT OF A CASE OCCURRING IN THE CERVICAL SPINE

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THE occurrence of giant cell tumor of the cervical spine is thought to be sufficiently rare to justify reporting a case of benign giant cell tumor in which there was destruction of a part of the body, the laminae and the spinous process of the fourth cervical vertebra and in which there was complete recalcification of the tumor and relief of symptoms following roentgen therapy.

Rix and Geschickter,[29] in an analysis of 291 tumors of the spine, found 58 cases of primary tumors of which 15 were giant cell tumors. Kolodny,[17] in the analysis of the material of the Bone Registry in 1927, found that giant cell tumors occurred in the spine in 8 per cent of cases. In Table I are listed the cases that have been collected from the literature. Some cases may have been missed but the list is sufficiently complete to indicate that the cervical spine is an infrequent location of giant cell tumor of the spine, 12 out of 91 cases, or 13.1 per cent.

Several other reports are listed in the references but it is felt that these cases are included in those given in the table as they are either earlier reports by the same group of authors or from the same institution. Murphy's[25] case is interesting because he reports a giant cell tumor of the lumbar vertebra in which operation was thought inadvisable and in which the patient refused radiation therapy. The case was followed and healed by calcification. A pathological fracture had occurred and this probably stimulated healing.

While there is still disagreement regarding some phases of the pathology of giant cell tumor, it is now generally agreed that while a majority of giant cell tumors are benign, there are cases which are either malignant from the outset or which undergo malignant changes. Some pathologists prefer to use the term benign and malignant giant cell tumor to designate the two groups. For detailed discussion of the disease, the pathological features of the publications the reader is referred to the publications by Rix and Geschickter,[29] Geschickter and Copeland,[11] and Jaffe, Lichtenstein and Portis,[14] Coley and Higinbotham[4] have briefly summarized the theories as to the

TABLE I

REPORTED CASES OF GIANT CELL TUMOR OF THE SPINE

Author	Year	Cases Giant Cell Tumor of Spine	Cases in Cervical Spine
Lewis[18]	1924	17	1
Kolodny[17]	1928	8	?
Cotton[6]	1928	1	0
Bower, Clark and Davis[1]	1930	14	1
Santos[30]	1930	2	1
Lindsay and Crosby[19]	1933	1	1
MacFarlane and Linell[20]	1933	1	1
Milch[21]	1934	1	1
Murphy[25]	1935	1	0
Peirce and Lampe[26]	1936	5	0
Duncan and Ferguson[8]	1936	1	0
Cleveland[7]	1937	1	1
Cabot Case 23081[4]	1937	1	1
Rix and Geschickter[29]	1938	15	1
Brunschwig[3]	1938	1	0
Jenkinson, Hunter and Roberts[15]	1938	2	0
Willard and Nicholson[35]	1938	1	1
Coley and Higinbotham[4]	1938	3	0
Richards and Singleton[28]	1938	2	1
Meyerding[21]	1941	10	1
Gershon-Cohen[12]	1943	3	0
TOTAL		91	12

mode of production or the cause of giant cell tumor as follows:

1. Neoplastic theory which assumes a true tumor originating in the bone marrow.

2. A non-neoplastic theory which holds that the condition is not a tumor but the result of chronic inflammation or chronic irritation, i.e. a faulty repair phenomenon.

3. Traumatic theory which assumes that an injury induces a subcortical hemorrhage in cancellous bone, and the area gradually extends and progressively destroys more and more bone.

Geschickter and Copeland[11] believe that the benign giant cell tumor is a phase of normal bone development which has extended beyond normal due to overactivity of the osteoclasts. Jaffe, Lichtenstein and Portis[14] would exclude the various variants of giant cell tumor. They disagree with many of the ideas advanced by Geschickter and Copeland.

While giant cell tumor can occur at any age, it is generally agreed that it most frequently occurs during the second and the first part of the third decade of life. Jaffe, Lichtenstein and Portis believe that if the various variants of giant cell tumor are excluded, the lesion will almost always be found in persons over twenty years of age, and that a considerable number of the tumors will prove to be malignant.

The spindle cell variants of the tumor occur commonly in vertebrae, flat bones, and bones of the hands and feet. They tend to heal readily and the prognosis is good. The case to be reported is a spindle cell variant type of giant cell tumor.

As pointed out by Kirklin and Moore,[16] roentgenograms of giant cell tumors may show the trabeculated appearance often described as the typical roentgen finding in giant cell tumor or may show a preponderantly lytic lesion with large areas of the bone completely absorbed. In the more advanced cases, the lytic areas may extend to the cortex, obliterating its shadow on the roentgenogram and the tumor may extend into the adjacent soft tissue. These authors suggest that the two types of roentgen findings probably represent different phases of the same process and not two different types of pathological change. The case to be reported is of the lytic type.

Roentgen therapy has long been recognized as a suitable means of treating benign giant cell tumor and its use has grown in favor with surgeons and pathologists as well as radiologists during the past twenty years. Kolodny[17] and many others advocate the use of radiation therapy without a biopsy in cases showing characteristic roentgen findings as recorded on the roentgenogram, and state that in those cases in which doubt exists as to the diagnosis from the roentgenogram the doubt will probably exist after study of the tissue. In their series, 20 per cent of cases treated by curettage recurred. In the group reported by Rix and Geschickter,[29] there was 25 per cent recurrence following curettement. Kolodny and others believe that when curettement is done and the lesion does recur, subsequent irradiation does not give as good results as in the uncuretted lesion. Another reason given for avoiding biopsy or curettage is the possibility of a superimposed infection following operation.

Brailsford,[2] in his excellent summary, states that the characteristic appearance of a giant cell tumor on the roentgenogram can be easily recognized. Because of the ease of diagnosis by one sufficiently experienced, and the excellent results from roentgen therapy it is unnecessary to do a biopsy. He gives the following limitations and disadvantages in regard to biopsy:

1. It does not reveal any additional features; it merely confirms the radiographic evidence; it may be misleading.

2. It weakens the stability of the bone; it may fracture the bone, or damage the joint surface, and make amputation appear essential.

3. It removes the scaffolding on which repair can be built up and so delays restitution.

4. It fails to reveal whether or not the tumor will form metastases. Tumors presenting the same histological structure may be eradi-

cated by local curetting or may metastasize and kill the patient.

5. It may actually disseminate the tumor cells.

6. It is an added risk to the patient.

7. There is evidence which suggests that the surgical trauma may incite malignant metaplasia in some cases.

Rix and Geschickter,[29] on the other hand, advocate curettement followed by roentgen therapy. Many surgeons advocate curettement and filling the defect with bone chips when the lesion is accessible, and give as one of the principal reasons for selecting this mode of treatment the fact that quicker end-results may be obtained. Where the lesion is located in the spine, the case is usually referred for roentgen therapy because of inaccessibility for surgery. It would seem that the mode of treatment will have to be determined at present for each case and that all phases of the individual case will have to be considered.

The dose of roentgen radiation most advocated has been a tumor dose of 3 to 5 erythemas delivered to the tumor over a period of several months in divided series, approximately 1 erythema dose at each series of treatments and the series of treatments administered at monthly intervals. One reason for the divided doses has apparently been that in some cases the tumor enlarges and symptoms are aggravated following roentgen therapy. After a few weeks the symptoms subside and the tumor undergoes recalcification. In the present case, the treatments were given at a little more rapid rate; there was no increase in the size of the tumor, and the patient experienced no aggravation of symptoms. Whether or not aggravation of symptoms is less apt to occur in the spindle cell variant of giant cell tumor cannot be determined from a review of the literature.

CASE REPORT

The patient was a male, aged twenty, who gave a history of having injured his neck and back in a truck accident September 1, 1942. There was considerable pain in the neck at this time and stiffness and some pain continued for a three month period. Early in 1943 he was accidentally struck in the neck and complained of stiffness and pain in the neck radiating down the right shoulder with weakness in the arm and numbness along the little finger. During this same period, there was a small amount of pain in the left arm and some numbness in the little finger of the left hand. The radiating pain and numbness became worse during April, 1943, and continued to slowly increase in intensity until August 14, 1943, when he entered an overseas station hospital. At that time a neurological examination did not reveal any evidence of organic pathology. Roentgenograms of the cervical spine made at that time showed a destructive lesion of the spinous process of the fourth cervical vertebra. Jarring of his neck caused sensory changes in the upper extremity and the patient complained of an increased amount of radiating pain down both arms and considerable weakness of both arms.

The patient was transferred to a general hospital overseas where a careful examination revealed that there was no muscle group atrophy or demonstrable weakness. A biopsy was done and a tumor which was grayish in color, moderately bloody, and quite friable, was found between the third and fifth spinous processes in the cervical area, apparently originating in the spinous process of the fourth cervical vertebra.

Roentgenograms made at the general hospital overseas revealed that the spinous process, the laminae, the inferior facets and portions of the superior facets of the fourth cervical vertebra showed complete loss of normal bone structure. The destruction was more marked on the right side than on the left. The bone that remained in the involved areas appeared to be finely honeycombed and of an amorphous character. The vertebral body of the fourth cervical vertebra appeared to be partly decalcified, but its main outline still appeared to be intact. The vertebrae above and below the fourth cervical showed no such destructive process, but there was a slight forward displacement of the body of the third on the fourth cervical vertebra as a result of the destructive lesion in the fourth cervical vertebra.

At the time the biopsy was taken, August 2[illegible], 1943, the blood sedimentation rate was [illegible] per hour, phosphoesterase 1.5 Bodansky units [illegible]

serum calcium 10.8, phosphorus 4, blood count normal, serology negative, urine normal, spinal fluid count cell count 2, gold curve normal, spinal fluid protein 50 mg. per 100 cc.

The patient was admitted to Letterman General Hospital September 30, 1943. Roentgen

Fig. 1. November 4, 1943. Roentgenogram showing destruction of the spinous process, both laminae, and a portion of the body of the fourth cervical vertebra.

examination of the cervical spine at this time confirmed the previous findings and showed a little more destruction of the vertebral body, but there were no other apparent changes. There had been no apparent change in the subjective symptoms which the patient suffered and his head had been supported in a cast or a traction apparatus since he first reported to the station hospital overseas. There was considerable pain in the neck and some radiating pain down both arms when the least amount of motion of the neck was allowed. The neurological examination was also negative. All of the laboratory procedures were repeated and the previous negative findings were confirmed. A complete skeletal survey did not reveal any other areas of involvement. The patient was presented to the tumor board and treatment was delayed until the diagnosis of the tissue removed at the biopsy could be confirmed by the pathologists at Letterman General Hospital and the opinion of the Army Medical Museum obtained. After all of the data had been assembled, roentgen therapy was started on November 3, 1943.

Report of Tissue From Overseas Hospital. Gross: Specimen consists of several small pieces of brownish-gray tissue, the largest of which measures 1.5 by 1.6 by 0.3 cm. Some of these specimens contain small spicules of bone. Cross section of the pieces that do not contain bone reveals a grayish-brown surface in which a few flecks of hemorrhage are seen. The outer surfaces of the specimens are almost warty in character. Cross section reveals a few hemorrhagic areas in the tissue. The tissue is very friable. Microscopic: Section consists of neoplastic tissue in which several features of interest are noted. The stroma is composed of two types of cells. The great majority are connective tissue spindle cells showing no hyperchromatism and exhibiting no mitoses. The other cell type present is the endothelial cell. It is thought that these are the origin of the giant cells. Xanthoma cells are seen. These are

Fig. 2. December 17, 1943. Roentgenogram made six weeks after the administration of 1,380 r to the tumor shows considerable recalcification of the entire tumor area.

pale, epithelioid and probably contain fat or cholesterol esters. A moderate amount of hemosiderin pigment is scattered diffusely through the section. Numerous small capillaries

FIG. 3. February 6, 1944. Roentgenogram showing further recalcification, one month after completion of second course of roentgen therapy. The second series consisted of 690 r delivered to the tumor.

are found and one or two areas of hemorrhage are seen. There is evidence of bone necrosis, for two areas in the section are bluish staining, amorphous and resemble necrotic bone tissue. No osteoblasts are seen and no osteogenic activity is noted. The unusual feature of the section is the presence of a moderate number of giant cells. These contain from 5 to 35 small, separate nuclei. They are not hyperchromatic. The cytoplasm is granular and pink-purplish staining. These nuclei pack the cell and some are clumped in the center. None are peripherally arranged. No capsule is seen in these sections. A moderate amount of collagen is present in the stromal tissue.

This tissue falls into the benign giant cell tumor group. There is no evidence of osteogenic sarcoma, carcinoma or tuberculosis. Because of the difficulty of completely removing all of the tumor tissue and mindful of the fact that repeated curettage occasionally transforms these tumors into malignant growths, roentgen therapy is probably the treatment of choice in this case. Diagnosis: Giant cell tumor of bone, benign.

Microscopic Examination at Letterman General Hospital. In areas, the lesion presents the typical appearance of benign giant cell tumor. Other portions of the growth, however, are more fibroblastic and show associated production of cartilage and osteoid tissue. It is not entirely clear whether these latter areas are compatible with a healing process in a malignant lesion. It is considered possible that we may be dealing with a secondary giant cell reaction in a malignant bone tumor. One fragment of the specimen consists of acute inflammatory exudate. The material is being forwarded to the Army Medical Museum for consultation.

Army Medical Museum Report. The diagnosis in this case is believed to be the so-called

FIG. 4. April 1, 1944. Final roentgenogram showing complete recalcification of the entire tumor. The total amount of roentgen radiation delivered to the tumor was 2,070 r and was concluded three months before this roentgenogram was taken.

fibrous dysplasia of bone. It will be noted that the main lesion is a fibrous one from which metaplastic bone trabeculae are formed. The occasional giant cells present appear to be osteoclasts in the region of hemorrhage, both fresh and old. The presence of cartilage in this lesion is not contradictory. It would be interesting to know whether there are multiple lesions in this case.

In spite of the slight disagreement in the microscopical diagnosis, it was felt that when all of the findings in the case were considered, we were dealing with a giant cell tumor and that roentgen therapy was the treatment of choice.

Therapy. Between November 3 and 13, 1943, the patient received 1,000 r roentgen radiation to each of two lateral 10 by 10 cm. fields centered over the involved area. Alternate fields were used daily. The factors used were 200 kv.; added filtration 0.5 mm. Cu plus 1.0 mm. Al; 18 ma.; output 28.5 r per minute, measured in air; 50 cm. skin target distance; half-value layer, 0.9 mm. Cu. The estimated dose delivered to the center of the tumor was 1,380 r.

Between January 1 and 5, 1944, 500 r additional was given to each field, treating both fields daily. The factors used were the same and the estimated tumor dose for the second series of treatments was 690 r, which made the total tumor dose for the two series of treatments 2,070 r.

Roentgenograms of the cervical spine made on December 17, 1943, showed extensive recalcification of the tumor, the main portion of the mass lying in the space between the spinous processes of the third and fifth cervical vertebrae. At an earlier date, the patient had noticed that the pain in his upper extremities on the slightest motion of the head had diminished and by December 17, 1944, this pain had practically disappeared. During all this time, and until the middle of March, 1944, the head and neck were supported either by a body cast or a special brace. The fact that this support was constantly applied from the time the lesion was first discovered until complete recalcification occurred is probably responsible for the fact that the lesion healed without any deformity of the spine and with no damage to the spinal cord. Roentgenograms made at intervals of a few weeks after December 17, 1944, showed increasing density of the callus. By mid March, 1944, the callus appeared so firm that the brace which supported the head and neck was discarded. There was no recurrence of the pain which had completely disappeared before this time. Neurological examination was again negative and the patient was judged to be apparently cured and transferred to another Army hospital for observation and disposition.

SUMMARY

The incidence of giant cell tumor of the spine is briefly reviewed, and the incidence of involvement of the cervical spine noted.

A case is reported which was diagnosed as a spindle cell variant of giant cell tumor on the basis of the history, physical and roentgen findings and study of tissue removed at biopsy, although there was some disagreement as to the microscopical interpretation of the tissue. Complete recalcification occurred following roentgen therapy with relief of the patient's symptoms. It is believed that the good result obtained (healing without deformity of the spine) was influenced by the fact that adequate support was applied to the head and neck from the time the lesion was first discovered and to the fact that no extensive curettage was done.

REFERENCES

1. Bower, J. O., Clark, J. H., and Davis, L. Management of giant cell sarcoma of the vertebrae. *Arch. Surg.*, 1930, *21*, 313–329.
2. Brailsford, J. F. Diagnosis and treatment of osteoclastoma. *Radiology*, 1944, *43*, 35–38.
3. Brunschwig, A. Observations on changes occurring at benign giant cell tumor sites several years following treatment by conservative measures. Am. J. Roentgenol. & Rad. Therapy, 1938, *40*, 817–827.
4. Cabot Case 23081. Benign giant cell tumor of the spine. *New England J. Med.*, 1937, *216*, 348–349.
5. Coley, B. L., and Higinbotham, N. L. Giant-cell tumor of bone. *J. Bone & Joint Surg.*, 1938, *20*, 870–884.
6. Cotton, A. Giant cell tumor of the spine, with report of a case. Am. J. Roentgenol. & Rad. Therapy, 1928, *20*, 18–24.
7. Cleveland, M. Giant-cell tumor of cervical spine. *Surg. Clin. North America*, 1937, *17*, 243–250.

8. DUNCAN, G. A., and FERGUSON, A. B. Benign giant-cell tumor of fourth lumbar vertebra. *J. Bone & Joint Surg.*, 1936, *18*, 769–772.
9. DYKE, C. S. Metastasis of "benign" giant-cell tumour of bone (osteoclastoma). *J. Path. & Bact.*, 1931, *34*, 259–263.
10. FREUND, E., and MEFFERT, C. B. Giant cell tumors; experience with surgical and roentgen treatments on material of 15 cases. AM. J. ROENTGENOL. & RAD. THERAPY, 1937, *37*, 36–45.
11. GESCHICKTER, C. F., and COPELAND, M. M. Tumors of Bone. Revised edition. American Journal of Cancer, New York, 1936.
12. GERSHON-COHEN, J. Giant-cell tumors; radiation therapy and late results. *Radiology*, 1943, *41*, 261–267.
13. HERENDEEN, R. E. Results in röntgen-ray therapy of giant-cell tumors of bone. *Ann. Surg.*, 1931, *93*, 398–411.
14. JAFFE, H. L., LICHTENSTEIN, L., and PORTIS, R. B. Giant cell tumor of bone; its pathologic appearance, grading, supposed variants and treatment. *Arch. Path.*, 1940, *30*, 993–1031.
15. JENKINSON, E. L., HUNTER, A. F., and ROBERTS, E. W. Giant cell tumor of the vertebrae. AM. J. ROENTGENOL. & RAD. THERAPY, 1938, *40*, 344–347.
16. KIRKLIN, B. R., and MOORE, C. Roentgenologic manifestations of giant-cell tumor. AM. J. ROENTGENOL. & RAD. THERAPY, 1932, *28*, 145–150.
17. KOLODNY, A. Bone sarcoma; primary malignant tumors of bone and giant cell tumor. *Surg., Gynec. & Obst.*, 1927, *44*, 1–214.
18. LEWIS, D. Primary giant cell tumors of vertebrae. *J. Am. M. Ass.*, 1924, *83*, 1224–1229.
19. LINDSAY, M. K., and CROSBY, E. H. Giant-cell tumor of second cervical vertebra. *J. Bone & Joint Surg.*, 1933, *15*, 702–704.
20. MACFARLANE, J. A., and LINELL, E. A. Benign giant-cell tumor of third cervical vertebra. *Brit. J. Surg.*, 1934, *21*, 513–518.
21. MEYERDING, H. W. Benign and malignant giant-cell tumors of bone; diagnosis and result of treatment. *J. Am. M. Ass.*, 1941, *117*, 1849–1855.
22. MEYERDING, H. W. Treatment of benign giant-cell tumors. *J. Bone & Joint Surg.*, 1936, *18*, 823–841.
23. MEYERDING, H. W. Giant-cell tumor of spine. *Surg. Clin. North America*, 1931, *11*, 778–783.
24. MILCH, H. Giant cell tumor of spine. *Am. J. Cancer*, 1934, *21*, 363–367.
25. MURPHY, G. W. Giant cell tumor of spine. AM. J. ROENTGENOL. & RAD. THERAPY, 1935, *34*, 386–394.
26. PEIRCE, C. B., and LAMPE, I. Giant cell bone tumor; further observations on treatment. *J. Am. M. Ass.*, 1936, *107*, 1867–1871.
27. PEIRCE, C. B. Giant-cell bone tumor; consideration of morphology of this neoplasm, response to surgical and radiation therapy, and report in detail of two apparently malignant cases. AM. J. ROENTGENOL. & RAD. THERAPY, 1932, *28*, 167–191.
28. RICHARDS, G. E., and SINGLETON, A. C. Giant-cell tumors of spine. *Radiology*, 1938, *30*, 43–51.
29. RIX, R. R., and GESCHICKTER, C. F. Tumors of spine. *Arch. Surg.*, 1938, *36*, 899–948.
30. SANTOS, J. V. Giant cell tumor of spine. *Ann. Surg.*, 1930, *91*, 37–43.
31. SIMMONS, C. C. Malignant changes occurring in benign giant cell tumors of bone. *Surg., Gynec. & Obst.*, 1931, *53*, 469–478.
32. STEWART, F. W., COLEY, B. L., and FARROW, J. H. Malignant giant cell tumor of bone. *Am. J. Path.*, 1938, *14*, 515–536.
33. WILLARD, DEF. P., and NICHOLSON, J. T. Giant cell tumor of cervical spine. *Ann. Surg.*, 1938, *107*, 298–302.

HYPERTROPHIC OSTEOARTHROPATHY

CASE REPORT*

By EDWARD M. KLINE, M.D.
CLEVELAND, OHIO

IN 1935 a patient was admitted to the Medical Service of the University Hospital, Ann Arbor, Michigan, with pronounced clubbing of the fingers and toes associated with widespread skeletal involvement. Interest in the general subject of hypertrophic osteoarthropathy was thus provoked and a brief review was published in the *University Hospital Bulletin*[4] but without any illustrations from this interesting case. During this interval nothing has come to my attention that so well illustrates the universal distribution occasionally seen in this syndrome and for this reason the opportunity has been taken to report the case in some detail.

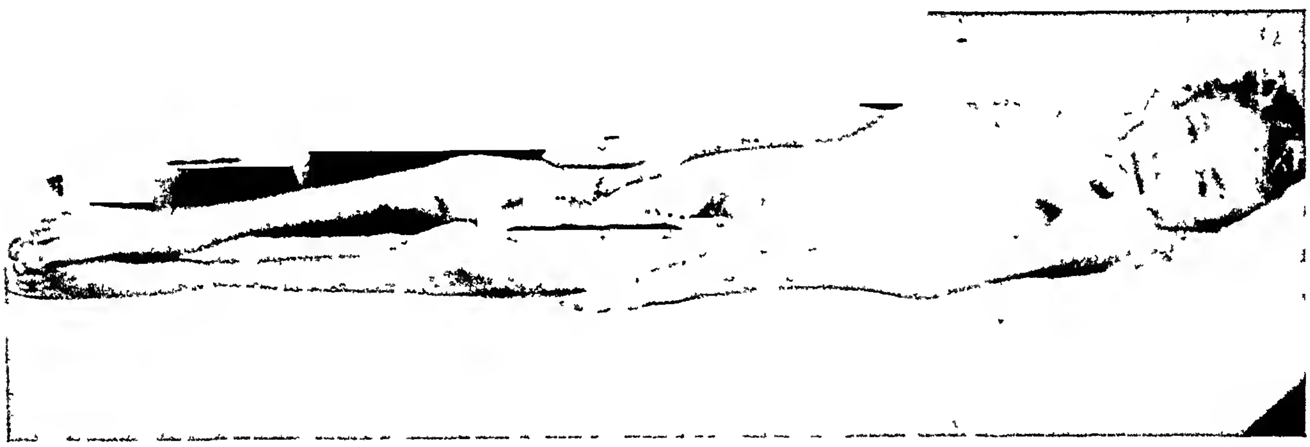

FIG. 1. Extreme emaciation, genital underdevelopment, lack of pubic hair, and marked clubbing of the fingers and toes.

CASE REPORT

W. K., male, white, aged fourteen, was admitted to the University Hospital November 7, 1935. The present illness dated back to 1925 when the patient was four years old. At that time he had a painless swelling of the right knee from which tuberculous material was removed at operation. The next year his mother noticed a lump on his back and he was admitted to another hospital with a diagnosis of Pott's disease involving the fifth, sixth and seventh dorsal vertebrae. This gradually subsided and from the age of eight to thirteen he was well enough to attend school. Numerous roentgenographic studies were made of the skeleton and the chest but at no time was there evidence of pulmonary involvement.

One year before admission, pulmonary symptoms commenced. At first there was only slight cough but five months before entry the cough became much worse and was accompanied by marked shortness of breath. There were occasional chilly sensations, night sweats, and great loss of weight.

Physical Examination. The temperature was 102.2° F., pulse 140, respirations 36, and blood pressure 120/50. The patient was an extremely emaciated and malformed boy whose development was about that of a ten year old child (Fig. 1). The skin was dry and bronzed in color. The eyes were deep set, the pupils being normal and reacting to light and in accommodation. There was a fetid odor to the breath, but the teeth were in fairly good condition. Examination of the thorax showed a tremendous flare of the costal margins with prominent ribs and

* I wish to express my appreciation to the Departments of Medicine and of Roentgenology of the University of Michigan for permission to publish the case and to Dr. John F. Holt and Dr. Harry Hauser for help in collection of material and preparation of the manuscript.

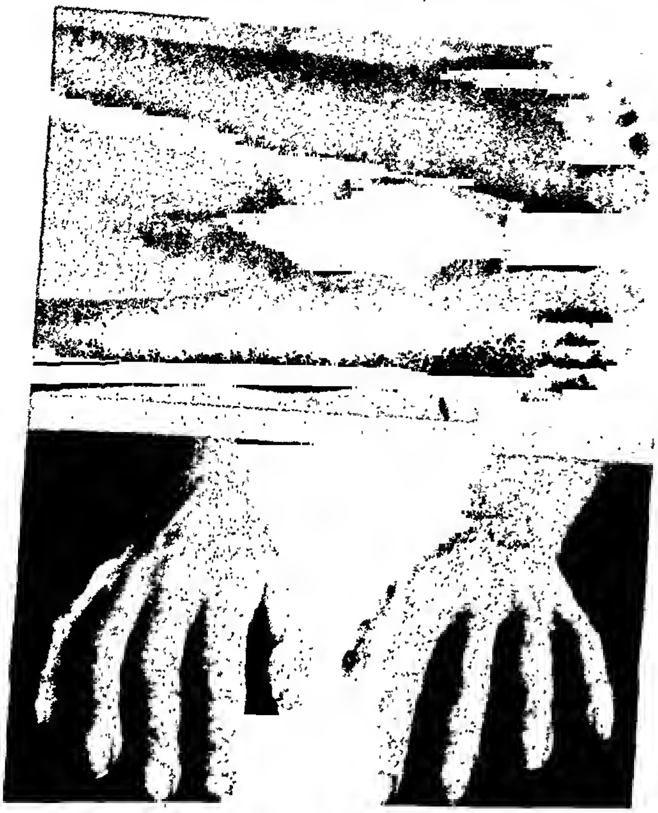

FIG. 2. Marked clubbing of fingers and toes.

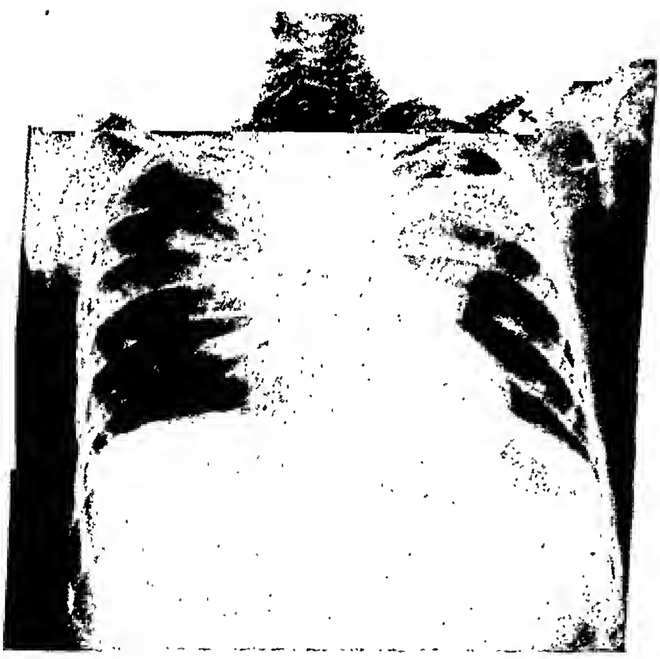

FIG. 3. Roentgenogram of the chest showing the large abscess cavity in the left apex and the paravertebral abscess extending beyond the right hilum.

thin chest wall. The percussion note was hyperresonant except at the left apex where there was dullness. In this same area there was marked harshness of the breath sounds and many crackling râles. The heart was overactive and a systolic murmur was audible over the entire precordium. There was an operative scar in the left flank. No abdominal viscera were palpable. Superficial lymph nodes were enlarged. There was no pubic or axillary hair and the genitals were underdeveloped. The extremities were thin with marked clubbing of the fingers and toes (Fig. 2).

Laboratory Studies. An anemia with 58 per cent hemoglobin and 2.72 million erythrocytes per cubic millimeter of blood was present. The cells were slightly hypochromic. The white blood cell count was 12,500 per cubic millimeter of which 76 per cent were polymorphonuclear cells. A glucose tolerance test was normal; the blood phosphorus was 3.9 mg. per 100 cc. and the calcium 8.9 mg. per 100 cc.

FIG. 4. The paravertebral abscess in the dorsal region is better demonstrated in this view. Numerous calcified tuberculous foci are present in the spleen. Vertebral destruction is seen in the regions of the sixth to the ninth thoracic, first and second lumbar and first sacral segments.

Ten direct examinations of the sputum for tubercle bacilli were negative although these organisms were cultured from both the sputum and gastric washings.

Roentgen Studies. A posteroanterior roentgenogram of the chest (Fig. 3) showed a large cavity with a fluid level occupying the left apex and a less well defined semicircular shadow of increased density extending out from the right hilum. This shadow on the right was demonstrated to contain fluid when heavy exposures with a Potter-Bucky diaphragm were made (not illustrated).

Fig. 5. Lateral view of the spine better demonstrating the destruction of the vertebral bodies.

A single anteroposterior roentgenogram of the thorax and abdomen (Fig. 4) showed destruction of the vertebral bodies in the regions of the sixth, seventh, eighth and ninth thoracic, first and second lumbar and first sacral segments. Numerous calcified nodules were seen in the region of the spleen. The crescentic shadow in the right hilum was again shown and was considered to represent a paravertebral abscess.

There was a symmetrical and almost universal elevation of the periosteum with subperiosteal new bone formation. This was most striking in the long bones (Fig. 6, 7, 8, 9 and 10) where it extended from the proximal to the distal epiphysis, but was also present to a less pronounced degree in the left scapula, clavicles, and ribs (Fig. 3 and 4). This lamination gave an "onion skin" appearance and at the distal end of the left humerus five distinct layers could be seen (Fig. 7 and 8*B*). Generalized osteoporosis was present.

Clinical Course. The patient was given transfusions and general supportive treatment. The spine was fixed by a posterior plaster shell and anterior frame. The pulmonary disease was so far advanced that no specific measures could be employed. He was transferred to another hospital for sanatorium care where he died March 7, 1936. No autopsy was performed.

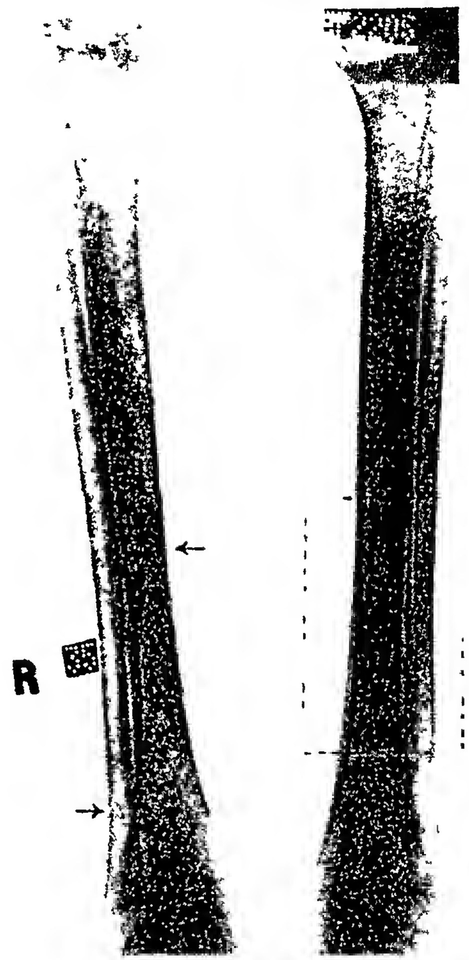

Fig. 6. Anteroposterior views of tibiae demonstrating periosteal new bone formation extending from the proximal to the distal epiphysis. Osteoporosis is pronounced.

The soft tissue manifestations of clubbing have attracted the attention of clinicians since the time of Hippocrates (whence the term hippocratic finger).[3] It was not un-

til 1889 when von Bamberger[1] reported 2 cases of bronchiectasis with skeletal involvement that correlation of clinical and pathologic findings was begun. Pierre Marie[5] reported the same condition one year later and attached to it the name of hypertrophic pulmonary osteoarthropathy. Although von Bamberger had priority, the condition is usually known by the name with which Marie designated it, less frequently as Marie's disease or Marie-Bamberger disease. Now that it is known that the bone changes may be secondary to other than pulmonary lesions this part of the name has been dropped and the condition is known simply as hypertrophic osteoarthropathy.

Fig. 7. Subperiosteal new bone formation involving the upper extremities.

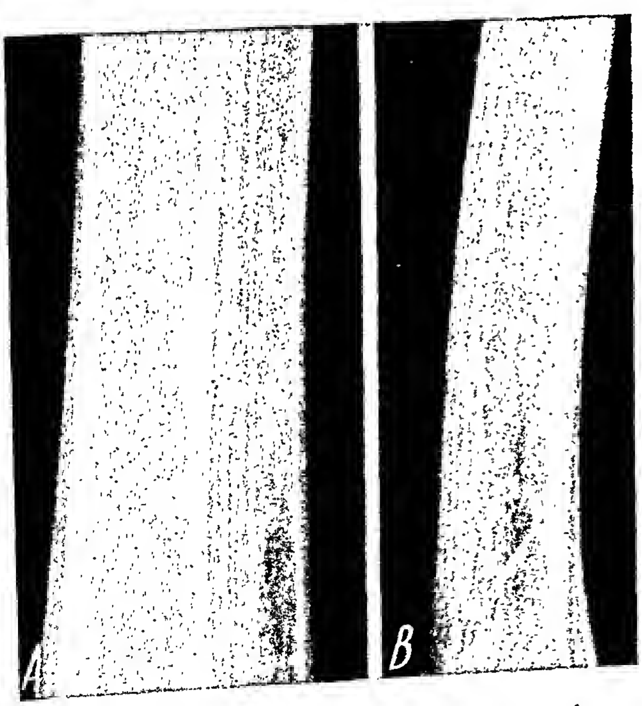

Fig. 8. Better demonstration of the laminated character of periosteal new bone formation of (*A*) left tibia and fibula and (*B*) left humerus. Magnification ×1.5.

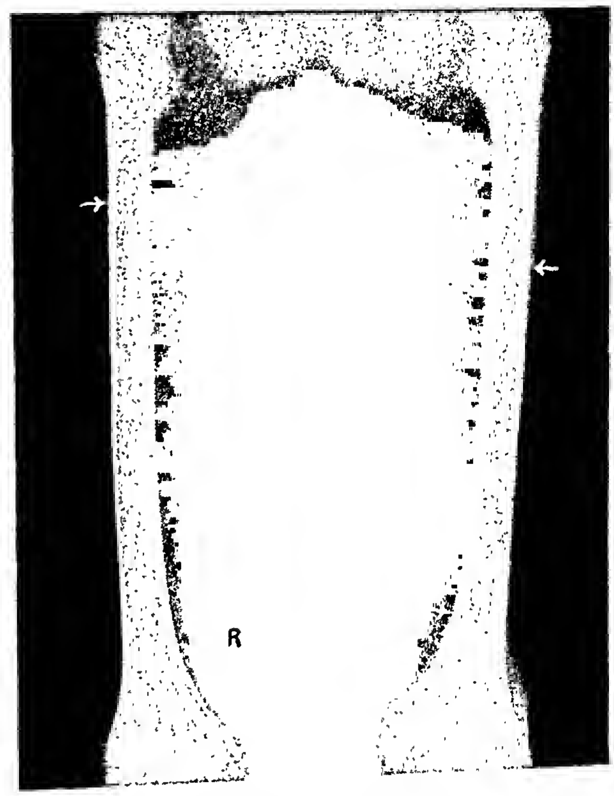

Fig. 9. Periosteal calcification less pronounced in femora.

Many theories have been advanced to explain the pathogenesis of this interesting condition. In general, most cases have seemed best explained either by "the toxic theory" or the "defective circulation theory."

Von Bamberger[1] and Marie[5] believed that the condition resulted from a toxin liberated by the bacterial decomposition of the bronchial secretions. Working on this hypothesis von Bamberger was the first to

attempt to produce the condition experimentally. He injected the bronchiectatic secretions into the rectum of young rabbits but his results were negative. Compere, Adams and Compere[2] were unsuccessful following artificially induced pulmonary collapse and lung abscess in dogs. More recently attention has been directed toward the circulation as the underlying defect. Mendlowitz and Leslie[7] simulated con-

Fig. 10. The bones of the right hand show definite hypertrophic periosteal changes in the shafts of the metacarpals and proximal phalanges. There is marked osteoporosis.

genital heart disease in dogs by anastomosing the left pulmonary artery to the left auricle. In one of two animals which showed increased cardiac output following this procedure, a definite subperiosteal proliferation developed which was similar grossly and histopathologically to hypertrophic osteoarthropathy. Mendlowitz[6] has published recently a communication on "Clubbing and Hypertrophic Osteoarthropathy" which is complete in all details and includes an excellent review of the literature to date.

The case reported here illustrates in a typical way the general features of the condition when it is present to an advanced degree. The long bones are nearly all involved, the distal epiphyseal region being more affected than the proximal as in the case of the humeri, tibiae, and fibulae. The profound osteoporosis characteristically accompanies the advancing periostitis either as an integral part of the process or as a result of the general debilitation of this individual. The distinctiveness of the laminations is remarkable and suggests that the factors operating in its production were not continuous but rather that these layers represent mile posts marking separate stages in the long illness of this patient.

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REFERENCES

1. von Bamberger, E. Case report. *Wien. klin. Wchnschr.*, 1889, *2*, 226.
2. Compere, E. L., Adams, W. E., and Compere, C. L. Possible etiologic factors in production of pulmonary osteoarthropathy. *Proc. Soc. Exper. Biol. & Med.*, 1931, *28*, 1083–1084.
3. Hippocrates. Prognostic No. 17. Loeb Classical Library, 1923, *2*, 25.
4. Kline, E. M. Chronic hypertrophic pulmonary osteo-arthropathy. *Univ. Hosp. Bull., Ann Arbor*, 1936, *2*, 28.
5. Marie, P. De l'ostéo-arthropathie hypertrophiante pneumique. *Rev. de méd.*, 1890, *10*, 1.
6. Mendlowitz, M. Clubbing and hypertrophc osteoarthropathy. *Medicine*, 1942, *21*, 269–306.
7. Mendlowitz, M., and Leslie, A. Experimental simulation in the dog of cyanosis and hypertrophic osteoarthropathy which are associated, with congenital heart disease. *Am. Heart J.* 1942, *24*, 141–152.

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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Twenty-eighth Annual Meeting: 1945, canceled.

EDITORIAL

BONE CHANGES IN ELECTRIC CURRENT INJURIES

THE increase in the use of electric current, not only the high tension current which supplies the city lighting systems and the great manufacturing industries, but the lower voltage household current which runs the various modern gadgets to lighten the many household duties, brings with it an increase in the number of injuries resulting from electric current accidents and burns.

The literature dealing with injuries due to electric current is not an extensive one. However, Palugyay as early as 1924 called attention to certain bone changes occurring in electric burns and he presented in a discussion of two cases the roentgen picture in bone injuries, particularly those of the upper extremities, namely the hands. Very little information has been added to this early description of these bone changes, which would seem to indicate that this is a chapter somewhat neglected in roentgen studies.

The most common bone change accompanying electric burns or injuries is the bone atrophy of the particular extremity involved in the accident and accompanying this bone atrophy is a sclerosis or hypertrophy of the periosteum, sometimes with alterations in the contour of the bone structure and rarefactions in the shaft of the bone, and occasionally a clear cut demarcation with sequestra formation.

The bone atrophy presents itself as a typical picture in the marked lessening of the calcium content (halisteresis), and this extensive loss of calcium content may involve all the bones of the injured extremity. This extreme atrophy may present itself as a roentgen picture several days after the injury, and indeed this is the usual occurrence. Associated with this loss of calcium content there may be a so-called cylindric sclerosis of the periostem, which type of sclerosis not only occurs in the diaphyses involved in the initial injury, but also the neighboring diaphyses, and this sclerosis may involve the bone structure even though the initial injury does not occur in the soft tissues immediately adjacent. The periosteal sclerosis may be a rather late manifestation, that is a matter of days following the shock or burn. The sclerosis is similar to that observed in spina ventosa or in an osteomyelitic process. This sclerosis when first observed may conform rather closely to the shaft of the bony contour; later the sclerosis appears to be separated somewhat from the bone by a translucent zone as if the periosteal proliferation is elevated from the shaft of the bone, and consequently there may appear along the shaft of the bone a rather thick calcium deposit.

Palugyay was not certain whether this so-called periosteal sclerosis represents an inflammatory reaction or results from a direct injury to the cells of the periosteum bringing about an ossification, or whether the changes are due to a subperiosteal hemorrhage.

Jaffé believes it is probable that the extensive bone changes are due not only to the initial electrical shock and the burn itself, but also to the changes brought about in the blood vessels and the nerves.

It is the extreme atrophy of the bone structures of the injured extremities which is the striking roentgen finding, and the periosteal reaction may not be observed. Associated with these marked bone changes is a certain degree of fuzziness or indistinctness in the appearance of the contour of the bones, and there is not infrequently a softening of the bone structures leading to contractural deformities of the extremity,

with considerable thickness of the cortex toward the end of the process, and not infrequently there may be actual sequestration of the necrotic bone. The type of atrophy which involves the skeleton is somewhat similar to that observed in Sudeck's atrophy.

In the initial bone changes, there may appear fine and delicate lines as shown in the roentgenogram. On superficial observation these are quite difficult to distinguish from normal bone structure and curiously enough these lines may not appear for two or three weeks and they present themselves in linear, zigzag or stellate type of bone pattern. These are among the earliest manifestations of the effect of electrical burns in the living bone, the extensive osteoporosis appearing sometimes weeks later, and associated with this osteoporosis there may be spontaneous fractures with sequestra as described. Unless the roentgenograms are examined carefully in cases suffering from electrical burns these earliest manifestations may be completely overlooked.

It is with the bone changes in electric current injuries that the roentgenologist is primarily concerned. Since Palugyay's communication describing these changes little of interest or importance has been added even by the later observers, and there are implications in this fact that further observations and experimental work on the skeletal changes in electric current injuries are needed.

REFERENCES

Palugyay, J. Knochenveränderungen bei Verletzung durch elektrischen Strom. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1924, *32*, 568–579.

Jaffé, R. H. Electropathology; review of pathologic changes produced by electric currents. *Arch. Path.*, 1928, *5*, 837–870.

Jellinek, S. Changes in electrically injured bones. *Brit. J. Radiol.*, 1926, *31*, 23–25.

Pearl, F. L. Electric shock; presentation of cases and review of the literature. *Arch. Surg.*, 1933, *27*, 227–249.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

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AMERICAN ROENTGEN RAY SOCIETY
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Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago.

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Secretary, Dr. U. V. Portmann, Cleveland Clinic, Cleveland, Ohio. Annual meeting: 1945, canceled.

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Secretary, Dr. J. S. Wilson, Mack Wilson Hospital, Monticello, Ark. Meets every three months and also at time and place of State Medical Association.

RADIOLOGICAL SOCIETY OF NORTH AMERICA
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GEORGIA RADIOLOGICAL SOCIETY
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Secretary, Dr. L. M. J. Freedman, 4800 Friendship Ave. Meets 6:30 p.m. at The Ruskin on second Wednesday, each month, October to May inclusive.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Murray P. George, Strong Memorial Hospital. Meets monthly on third Monday from October to May, inclusive, 8 p.m. at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary Dr. A. M. Popma, 220 N. First St., Boise, Idaho.

St. Louis Society of Radiologists
Secretary, Dr. Edwin C. Ernst, Beaumont Medical Building, St. Louis, Mo. Meets fourth Wednesday of each month, except June, July, August, and September, at a place designated by the president.

San Diego Roentgen Society
Secretary, Dr. Henry L. Jaffe, Naval Hospital, Balboa Park, San Diego, Calif. Meets monthly on first Wednesday at dinner.

San Francisco Radiological Society
Secretary, Dr. Carlton L. Ould, University of California Hospital, San Francisco 22. Meets monthly on the third Thursday at 7:45 p.m., first six months of the year at Lane Hall, Stanford University Hospital, and second six months at Toland Hall, University of California Hospital.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 p.m., September to May inclusive.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, 707 Walnut St., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. R. P. O'Bannon, 650 Fifth Ave., Fort Worth 4, Texas. Next meeting, Dallas, Texas, Monday, January 14, 1946.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 p.m. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 p.m., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. E. L. Flanagan, 116 E. Franklin St., Richmond, Va. Meets annually in October.

Washington State Radiological Society
Secretary, Dr. Thomas Carlile, 1115 Terry St., Seattle. Meets fourth Monday each month, October through May, College Club, Seattle.

X-ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly, third Thursday evening.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Medical Members' meeting held monthly on third Friday at 2:30 p.m. and Ordinary Meeting at same time on following Saturday, October to May, 32 Welbeck St., London, W.1.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month at 4:45 p.m. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. J. W. McKay, 1620 Cedar Ave., Montreal, P. Q.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

South America

Sociedad Argentina de Radiologia
Secretary, Dr. Guido Gotta, Buenos Aires, Argentina. Meetings are held monthly.

Sociedad Peruana de Radiologia
Secretary, Dr. Victor Giannoni, Apartado, 2306, Lima, Peru. Meetings held monthly except during January, February and March, at the Asociación Médica Peruana "Daniel A. Carrión, Villalta 218, Lima.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. Babaiantz, Geneva.
Secretary for German language, Dr. Max Hopf, Effingerstrasse 49, Bern. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad: USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 p.m.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

LAURISTON S. TAYLOR HONORED

The Bronze Star Medal for meritorious service was presented on October 26, 1945, to Dr. Lauriston S. Taylor, 4923 Battery Lane, Bethesda, Maryland, by Major General Samuel E. Anderson, Chief of Staff, Continental Air Forces, in General Anderson's office at Bolling Field, D. C. Dr. Taylor, who has been associated with the Operations Analysis Branch of the Army Air Forces, served in the European theater of operations from May, 1943, until June, 1945, being stationed in England, France, Belgium, Germany and Luxemburg.

The citation accompanying Dr. Taylor's award commended him for outstanding leadership, analytical ability and technical skill demonstrated while he was chief of the Operational Research Section of the 9th Bombardment Division. Under his direction, the efficiency of lead crews increased, a highly efficient program of bridge interdiction was scheduled and bombing accuracy greatly improved.

Dr. Taylor arrived in France shortly after D-Day to aid in an investigation of enemy targets hit by allied aircraft for an assessment of the effectiveness of our weapons against these targets.

A graduate of Cornell University, Dr. Taylor is a member of the American Physical Society, the Washington Academy of Medicine, the American Roentgen Ray Society and the Radiological Society of North America. He plans to return to his pre-war position as Chief of the X-Ray Section, Bureau of Standards, in Washington, D. C.

BRITISH HOSPITAL PHYSICISTS ASSOCIATION DIAGRAMS AND DATA SUB-COMMITTEE

Charts and diagrams often appear in the radiological literature which are too small to be of practical use; it would be convenient if there were some way of obtaining full size copies of the originals. Also institutions accumulate diagrams and data for their own use, which are not published but which would be useful to others if they were available.

The British Hospital Physicists Association has undertaken to provide such a clearing-house, and has issued a catalog of some 200 items which are available. These comprise a wide range of isodose curves and dosage calculation charts for roentgen rays and radium, diagrams of apparatus, tables of mathematical data, and a few books. Anyone having data to share can list it with the Secretary of the Association and anyone wishing to obtain any of the items can order them through him. The cost per item is moderate, and it is expected that it will be reduced when the scheme has been in operation long enough to build up a small reserve.

Detailed information as to what data are available, and current charges therefor can be obtained from the Secretary, Dr. J. Read, Radiotherapy Department, The London Hospital, Whitechapel Road, London E 1.

This is an excellent idea and one that might well be copied by radiological physicists in this country. Cooperation could then be developed between British and American groups for their mutual profit. No American organization exists analogous to the British Hospital Physicists Association, but physicists are well represented on the Standardization Committees of both the American Roentgen Ray Society and the Radiological Society of North America, and such a plan might come within their scope. Or it might appropriately be an activity of the American College of Radiology, with an advisory committee of physicists and radiotherapists. It is suggested that the subject be put before the various interested groups for consideration.

"COMMITTEE ON GROWTH" OF THE NATIONAL RESEARCH COUNCIL

The appointment of a Committee on Growth, with membership designed to be

broadly representative of the fields concerned in cancer research, both basic and clinical, has already been announced by the National Research Council of the National Academy of Sciences. The Committee was created, within the Division of Medical Sciences of the Council, as a result of action by the American Cancer Society designating the Academy as its scientific adviser for research.

The Committee wishes to call the attention of interested investigators to the general outline of endeavor which it proposes to foster and the general principles by which it will be guided. The Committee accepts the interpretation of its field of interest as including reliance on, contact with and support of research in the basic sciences bearing broadly on the whole phenomenon of growth.

The Committee has adopted the following major principles by which, so far as possible, it will be guided in its sponsorship of research and training programs:

(a) Desirability of long-term grants to projects of major importance.
(b) Grants, where possible, of such magnitude as to permit individual investigators to appoint associates for long-term training periods.
(c) Granting of fellowships to institutions for training of workers to acquire new techniques and wider experience.
(d) Maintenance of continuing individual contact with workers in the field.
(e) Provision, on a participating basis, for continuing economic security for professional workers.
(f) Liberal attitude toward the investigator's work, his publication and reports.

To assist it in the fulfillment of its advisory functions the Committee, on its part, will make free use of either *ad hoc* or standing subcommittees in specific fields of interest. Furthermore, it proposes to arrange conferences of competent groups for discussion of problems, for interchange of reports, etc.; make surveys to analyze problems or to determine progress in areas of special interest pertaining to cancer; evaluate, through study by subcommittees and by the main committee, basic and clinical research undertakings, and submit recommendations for support to the American Cancer Society; initiate and plan broad or specific programs of basic and clinical research, through activities of the subcommittees and main committee, and secure the cooperative efforts of investigators in the general undertakings.

The Committee has established a central office in the Washington headquarters of the Council where information on all phases of cancer research will be assembled and from which reports may be distributed to interested investigators.

Many members of the Committee have participated intensively in the broad programs of research conducted under the pressure of war. It is both the hope and the sanguine expectation of the Committee that the fruitful pattern of cooperative investigations so successfully established during the war years, can now be carried on, modified and tempered to existing needs, into the continuing war against disease.

Membership of the Committee, as now constituted, includes the following: Dr. C. P. Rhoads, *Chairman*, Dr. Florence R. Sabin, *Secretary*, Dr. A. R. Dochez, Dr. A. Baird Hastings, Dr. Charles B. Huggins, Dr. Donald F. Jones, Dr. C. C. Little, Dr. Carl R. Moore, Dr. John J. Morton, Dr. James B. Murphy, Dr. Eugene P. Pendergrass, Dr. Howard C. Taylor, Jr., Dr. M. A. Tuve, Dr. M. C. Winternitz.

Philip S. Owen, M.D. *For the Committee on Growth, Division of Medical Sciences, National Research Council*

2101 Constitution Ave.,
Washington 25, D. C.

EXHIBIT ON BONE TUMORS

A committee of the [illegible] Ray Society [illegible] Dr. C. H. Heacock, Chairman, Dr. [illegible]

Golden and Dr. C. E. Hufford to confer with Colonel A. A. deLorimier regarding the disposition of the extensive Exhibit on Bone Tumors of the late Dr. John T. Murphy of Toledo. The following decision has been made:

1. The original exhibit will be maintained permanently in Washington, D. C., in the Army Medical Museum.

2. The Army School of Roentgenology will make two copies of the exhibit. One set will be retained by the School for use in teaching. The other set will be the property of the American Roentgen Ray Society.

CELEBRATION OF FIFTIETH ANNIVERSARY OF DISCOVERY OF THE ROENTGEN RAY

Various professional and lay groups interested in the roentgen ray are celebrating the Fiftieth Anniversay of its discovery at a meeting to be held in the Cleveland Medical Library, Cleveland, Ohio, on November 8, 1945. In the afternoon there will be talks by a representative of one of the universities, a radiologist, a dentist, and a research industrialist. In the evening, after a short historical program, there will be an exhibit illustrating the uses of the roentgen ray in medicine, dentistry, public health and industry. The exhibit will be open to the public on Sunday afternoon, November 11.

The committee consists of Dr. Howard Dittrick, Chairman, J. T. McCarthy, L. O. Olson, H. J. Wallace, Dr. J. S. Driver, Dr. Otto Glasser, Dr. Harry Hauser, and Dr. J. A. Sweeney.

NEW ENGLAND ROENTGEN RAY SOCIETY

At the meeting of the New England Roentgen Ray Society to be held on November 16, 1945, at eight o'clock at the Harvard Club, Boston, the Fiftieth Anniversary of the discovery of the roentgen ray will be commemorated by the following special program:

The Use of Roentgen Rays in Art. William J. Elliott, M.D., Worcester, Mass.

Some Industrial Applications of Roentgen Rays. Paul E. Tivnan, M.D., Beverly, Mass.

The Application of Roentgen Rays to Crime Detection. Joseph T. Walker, Ph.D., Chief of State Police Laboratories.

Roentgen Rays as a Tool of the Physicist. Bertram E. Warren, Sc.D., Cambridge, Mass.

Roentgen Rays in Medicine. Merrill C. Sosman, M.D., Boston, Mass.

SEGUNDO CONGRESO MEXICANO DE CANCER

A cordial invitation is extended to the members of the American Roentgen Ray Society to attend the Segundo Congreso Mexicano de Cancer and Tercera Semana Medica de Occidente to be held in Guadalajara, Mexico, February 3 to 9, 1946. The President is Dr. Manuel Ribeling and the Secretary is Dr. Enrique Garcia Ruiz, Edificio Lutecia No. 123, Guadalajara, Jal., Mexico.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

X-Ray Isodose Curves. Compiled by the Staff of the Physics Department of the Royal Cancer Hospital (Free), London, S.W. 3. 45 kv., 60 kv., 140 kv. (peak), 200 kv., 400 kv. (peak), isodose curves. Reprint of Percentage Depth Dose Tables supplied with each set of curves. Isodose curves contained in stout cardboard portfolios. Complete set at £10.10*s*.0*d*. Royal Cancer Hospital (Free), Fulham Road, London, S.W. 3, England.

Tables and charts readily available to American radiologists give roentgen-ray depth doses along the axis of the radiation beam, for almost any desired set of physical factors. For points off the axis the dose is known to be less than that in the central position; toward the edge of the field the difference becomes marked. For satisfactory determination of dosage at any position off the axis, isodose charts are essential. Scattered charts of this sort are to be found in the literature, as parts of articles on radiation measurement; few of these are convenient for regular use, even if they present desired factors.

The Physics Department of the Royal Cancer Hospital (Free), recognizing the need for a wide variety of charts of this sort, has prepared a set covering a considerable range of qualities and field sizes. These are based on experimental work at the Hospital, supplemented by data from the literature. Each chart is printed in black, red, or green, on fairly transparent tracing linen, in actual size, so that it is convenient for use with life-sized anatomical diagrams.

The complete set comprises 66 charts as follows:

45 kv.—6 charts, small fields and short distances, appropriate to Philips contact equipment. Cost, £1.11*s*.6*d*.

60 kv.—8 charts, small fields and short distances, appropriate to Chaoul contact equipment. Cost, £1.11*s*.6*d*.

140 kv. (peak), 0.25 mm. Cu filter, 0.32 mm. Cu half-value layer (approximately 7 mm. Al half-value layer), 9 charts, small and medium fields, 15–25 cm. distance. Cost, £2.2*s*.0*d*.

200 kv. (peak), 1.0 mm. Cu plus 1.0 mm. Al filter, 1.5 mm. Cu half-value layer, 22 charts, small, medium, and large fields, including long and short axis for a few rectangular fields, 50 and 80 cm. distance. Cost, £3.3*s*.0*d*.

400 kv. (peak), 0.22 mm. Sn plus 1.7 mm. Al filter, 3.6 mm. Cu half-value layer, 21 charts for essentially the same fields and distances as the 200 kv. group. Cost, £3.3*s*.0*d*.

The 45 and 60 kv. sets are applicable only to the Philips and Chaoul contact equipment respectively. It should be noted that the former are drawn twice actual size. It is the opinion of this reviewer that the 140 kv. (peak), 0.25 mm. Cu filter combination is not now widely employed in this country.

The values for the doses along the axis of the beam, for 200 and 400 kv. (peak) are in good agreement with data currently used in the United States; these charts should be useful to every radiologist for determination of dose to any part of a region under treatment. Qualities corresponding to half-value layers of 1.0 or 2.0 mm. Cu are probably more frequently employed here than 1.5 mm. Cu. However, since in this range differences are not large, satisfactory values for either 1.0 or 2.0 mm. Cu half-value layer can be obtained by making slight corrections. Values for distances and fields not included in the set can be determined by interpolation with the aid of tables.

The preparation of these charts has been painstaking, and radiologists are indebted to Dr. Mayneord and his associates for the manner in which it has been accomplished. It is to be hoped that they will be encouraged to provide others for the 100 kv. (peak) region, at 15 to 25 cm. distances, and for million volt beams.

Edith H. Quimby

Les bases physiques et biologiques de la roentgenthérapie. Par Paul Lamarque, Docteur ès Sciences; Professeur à la Faculté de Médecine de Montpellier; Directeur du Centre Régional contre le Cancer. Avec la collaboration de MM. Pierre Bétoulières, Jean Reboul, Edmond Debains et Pierre Lorimy. Préface de Mr. le Professeur Strohl. Paper. Pp. 530, with 284 illustrations. Paris: Masson et Cie, 1942.

Convinced that clinical radiology will make little further progress until radiologists are familiar with its basic physics and biology, the

author has undertaken to assemble this material in a comprehensive volume, and has done it well.

The nature and behavior of roentgen rays are thoroughly discussed, but with a minimum of mathematics. Roentgen-ray tubes of many types are described, and numerous transformer-rectifier circuits presented. The chapter on qualitative measurements is the best this reviewer has seen on that topic, including spectrometry, voltage measurements of various types, and the different schemes based on absorption measurements. Under quantitative measurements, a number of standard dosimeters are described in some detail. The section on practical dosimetry is rather disappointing in that it contains insufficient data for dosage calculation in actual therapy.

Basic radiobiology is as well handled as basic physics. Reversible and irreversible effects on the living cell, the phenomenon of radiosensitivity, and quality, intensity, and time factors are discussed. The action of roentgen rays on various tissues and organs is set forth in detail; relative radiosensitivities are given, and related to therapeutic possibilities, especially in the treatment of functional and inflammatory conditions. In relation to the biologic basis of clinical dosimetry, the importance of a study of tissue recovery is emphasized.

Radiation therapy techniques are discussed from the points of view of radiation quality, and of the spatial and temporal distribution of the dose. Under the first heading, much attention is given to very soft radiations—Bucky, Philips, and Chaoul type of equipment. Under the last, various techniques for fractionation of dose are presented, with little critical attention to discrepancies in the numerical data of different authors.

The hazards of radiation to patients and to personnel of a department of radiology are thoroughly discussed and desirable protective measures are outlined. The national French regulations are included.

A final chapter by Reboul contains an excellent summary of the various theories of biological action of radiation.

The book ends with an extensive bibliography, which, unfortunately, contains many misprints. Most of these arise in translations of titles and are unimportant, but in a considerable number of instances names of authors are misspelled or first names used instead of surnames, and in a cursory inspection several errors in dates were noted. The main text appears free from such mistakes. A serious handicap is the lack of an index. The table of contents is quite complete and detailed, but is not entirely satisfactory as an aid to finding pages for definite topics.

Edith H. Quimby

The Fundamentals of Electrocardiographic Interpretation. By J. Bailey Carter, M.D., F.A.C.P., Assistant (Rush) Professor, Department of Medicine, University of Illinois College of Medicine; Attending Staff, Cook County Hospital, Augustana Hospital, Chicago. Second edition. With a Foreword by Horatio Burt Williams, M.D., Dalton Professor of Physiology, College of Physicians and Surgeons, Columbia University, New York. Cloth. Price, $6.00. Pp. 406, with 309 illustrations. Springfield, Illinois: Charles C Thomas, 1945.

The title of this book is grossly misleading for the author fails to present adequate or accurate material to justify such a resounding label on the backstrip. Over one-third of the book is given over to the electrocardiographic changes associated with myocardial infarction. Much of this material is repetitious and poorly organized since the writer reprints here six papers, dealing with this subject, which he has previously published in medical journals, presenting them as separate chapters with practically no alterations. Relatively little importance is given to the QRS changes which occur in myocardial infarction and unduly great stress is placed upon the T wave alterations in this condition. The author tends to overemphasize the value of the electrocardiogram in following the progress of a patient who has had an acute coronary thrombosis, giving it a place above that of clinical observation. Examples of the writer's misconceptions regarding the electrocardiographic changes in coronary arterial disease are such statements as "an absent R_4 or Q_5 occurs with coronary sclerosis without infarction and may occur even in the absence of coronary disease" and "rarely, if previously absent, does a deep Q_3 appear following infarction." It is stated repeatedly that inverted T waves must be present in lead II to permit the electrocardiographic diagnosis of posterior myocardial infarction, yet the author repeatedly fails to adhere to this criterion in the diagnoses accompanying his own figures.

In this work a technique for recording the

precordial electrocardiogram is recommended which consists of placing the exploring electrode in the fifth interspace in the left midclavicular line and using first the right arm and then the left leg as the indifferent electrode. The two records made in this fashion will be different only insofar as the potential variations of the indifferent electrode are different. Undoubtedly, the use of such a technique for recording chest leads accounts in large measure for the author's experience that "chest leads, in only a small percentage of cases, assist in determining the occurrence, the location, and/or duration of myocardial infarction," an experience completely dissimilar to that which the reviewers have had with quite different methods. When in support of his technique the author states, "—no other combination of chest leads is supported by such a wealth of experience. No other method for recording chest leads is so simple and fool-proof. No other lead, or combination of leads, has afforded more information in routine practice," he is either being facetious or demonstrating, further, his lack of understanding of the fundamental nature of the precordial electrocardiogram and the observations of others in this field.

A great many erroneous diagnoses accompany the figures presented with the text. A few illustrative examples are: (a) in Figure 45, right axis deviation is not present; (b) the extrasystoles in Figures 84 and 259 are of ventricular rather than of nodal origin; (c) the six sets of records in Figure 114, all of which are said to be examples of coronary occlusion, show no significant QRS changes; (d) Figures 131 and 193 are examples of left bundle branch block but show no signs diagnostic of myocardial infarction; (e) transient left bundle branch block occurs in Figure 197A but is unrecognized; (f) rather nice examples of right bundle branch block plus anterior infarction are seen in Figures 203A and B, which are said to show "early anterior (apical) infarction"; and (g) Figure 262, which is said to show complete atrioventricular heart block, actually discloses numerous responses to supraventricular impulses, thereby more properly accounting for the variations in the form of the QRS complexes.

The writer employs a "newspaper" or "telegraphic" style which may account for much of the loose writing and many of the sweeping statements made. He cannot really mean it when he says, "An iso-electric or inverted T wave in all leads is practically pathognomonic of myxedema—," or "Electrocardiograms of diabetics are seldom normal," or "A previous angina pectoris is frequently absent following coronary occlusion."

Many of the figures are too small or of too poor technical quality for careful study. Although the errors in the figures are usually recognized in the text, lead V of Figure 210E is upside down and Figures 231 and 232 are upside down and backwards. A number of typographical errors are found in the text and legends.

This book has little to recommend it except the bibliography which is rather extensive and well arranged.

Francis F. Rosenbaum
Frank N. Wilson

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, M.D., B.S., M.A., 103 Rutledge Ave. Charleston, S. C.

DEVICE FOR SECURING PROPER ALIGNMENT IN LATERAL ROENTGENOGRAMS OF THE FEMORAL NECK

By WILLIAM P. GILMER, M.D.
Chesapeake and Ohio Hospital
CLIFTON FORGE, VIRGINIA

LATERAL views of the neck of the femur present no very difficult technical problems when the guiding anatomical points are accessible and proper alignment accurately obtained. When it is necessary to locate the pin which is being inserted for fixation of a fractured neck of the femur, the problem of accurate alignment may be difficult. It may be impossible to locate the guiding anatomical points on account of sterile sheets covering the patient. A failure to produce a satisfactory roentgenogram under these circumstances is disappointing. A very simple device for preventing these failures is described.

The device consists of a T-shaped ruler, the long arm 36 inches in length and the short arm 8 inches. The long arm is marked off in inches starting at the end which joins with the short arm (Fig. 1).

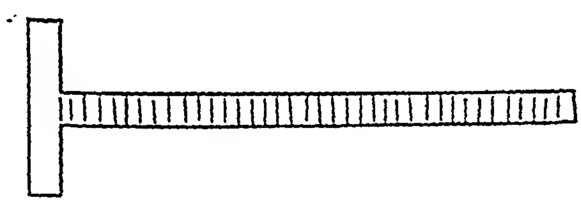

Fig. 1

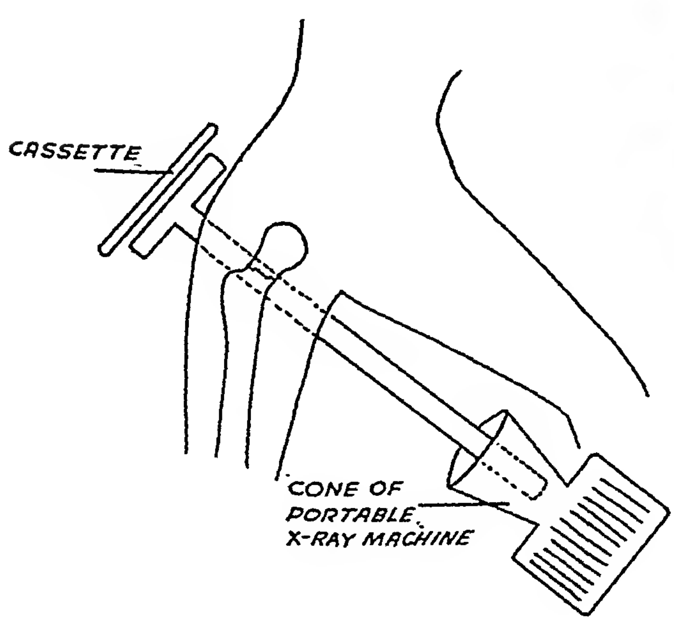

Fig. 2

Fig. 3

The use of the ruler is quite simple. Before the operation begins and while guiding anatomical points are accessible, the ruler is placed under the patient with the long arm crossing the mid-point of the

neck of the femur at right angles to the long axis of the neck and the short arm in the position where the cassette is to be placed. With this ruler in place proper positioning of the cone of the portable roentgen machine can be quickly and accurately made. By adding the previously obtained tube cone distance to the reading on the ruler at the point to which the cone reaches the tube-film distance is obtained. By using this distance and a suitable thickness of part technique all necessity for guess work will be avoided, both as to alignment and technical factors.

Figure 2 is a sketch illustrating the use of this ruler.

Figure 3 is a roentgenogram made with a 15 ma. portable machine using the above described ruler for obtaining proper alignment.

INDEX TO ABSTRACTS

ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

NECK AND CHEST

Blake, J. M. Primary carcinoma of the bronchus associated with foreign body. *Am. Rev. Tuberc.*, Jan., 1943, *47*, 109–111.

This report is concerned with a primary carcinoma of the lung which apparently developed about a small metal crucifix (measuring 4×7 mm.). This object was removed at the time of obtaining the biopsy and when the diagnosis of carcinoma was established. There was no history of aspiration of a foreign body but after detailed questioning, the patient remembered having lost the crucifix some six years previously, when he thought that he had swallowed it.

About nine months prior to the date of the biopsy, the patient had had what was thought to be an ordinary bronchitis, with severe cough, malaise, lassitude, fever up to 103°F., and some expectoration of blood-streaked sputum. Though the roentgen study was reported negative, re-examination of the roentgenogram showed a rounded density measuring about 3×3 cm. in the lower portion of the right lung.

As the fever subsided, the patient returned to his home but fatigue, cough and expectoration continued and he lost about 15 pounds. His white blood cell count reached 15,200 and there was a definite increase in the sedimentation rate. Roentgen studies indicated the presence of an atelectasis in the region where the small opacity had previously been visualized—and this led to the biopsy.—*A. A. de Lorimier.*

Hoyos, Jorge Meneses, and Quesada, J. J. Normal cardiovascular roentgen silhouette; studied by means of roentgenograms of the chests of cadavers after opaque solutions had been injected into the large vessels and chambers of the heart. *Arch. Int. Med.*, May, 1943, *71*, 666–674.

The authors have tried to determine clearly the relations that normally exist between the contour of the cardiac shadow in roentgenograms and the different chambers and large vessels of the heart. In Juarez Hospital of Mexico City, sodium iodide solution was injected into the large vessels and the chambers of the hearts of several cadavers. Roentgenograms were then taken of the chests of these cadavers placed in the dorsoventral position and in oblique position. The results of this study are given. It seems doubtful if this method of study is superior to that of angiocardiography developed by Robb and Steinberg.—*J. J. McCort.*

Crawford, J. Hamilton. Aneurysm of the heart. *Arch. Int. Med.*, April, 1943, *71*, 502–515.

Although aneurysm of the heart has been recognized for almost two centuries it is only recently that the antemortem diagnosis has been made with any assurance. The advent of

more thorough study of the patients with heart disease by roentgenologic methods has considerably increased the frequency with which the correct diagnosis is made. The author presents 13 cases, in 9 of which the diagnosis was proved at autopsy. In all of them there was well marked aneurysmal dilatation of the ventricular wall. In 4 of the group in which autopsy was performed diagnosis was made antemortem and 3 patients are still alive. One patient presented undisputable clinical evidence of the condition but permission for an autopsy could not be obtained.

Three of the patients presented here had no roentgen examination as cardiac aneurysm had not been suspected clinically. Eight showed enlargement of the heart and 3 a localized bulge. Angulation of the left ventricular wall contour was seen 3 times. Abnormal pulsations demonstrated by fluoroscopic or roentgen kymographic examination are frequently of the greatest value. Their character varies from a reversal of the normal type to absent pulsation. The pulsations were proved to be abnormal in the aneurysmal zone in 6 of these patients. Of these 4 showed an expansion during systole of the rest of the ventricle with ballooning out in a most striking manner in 2 of them; the other 2 had very small, or no pulsation. In none were pulsations of the normal type. Other authors have emphasized the value of localized pericardial adhesions in the diagnosis. This was not present in any of the cases reported here, but on autopsy adhesions to the pericardium and to the sac were seen in 6 cases. They were absent in 1, and in 2, there was no note as to its presence or absence. None of the patients in this study showed calcification in the wall of the sac or a thrombus contained therein. When calcification is seen it must be differentiated from calcification of the pericardium. The latter is on the surface and usually more diffuse, while in calcification of an aneurysm the calcification should be localized and not confined to the surface.

The roentgen examination is the most important aid in the diagnosis of cardiac aneurysm as changes in the contour can be, as a rule, clearly delineated. Unfortunately, the most common site for aneurysms is the apex which is the position in which the contour can be studied least effectively. At this point, the heart and diaphragmatic shadows mingle, which tends to obscure deformities of the cardiac contour. A diffuse, concentric apex rounded, or a broadened, blunted apex has been stated to be characteristic. These are, however, so frequently seen in patients suffering from hypertension or aortic insufficiency, which are relatively common condi ions, that it is very doubtful whether a satisfactory differentiation can be made. The apex region can be studied in more detail during very deep inspiration or after inflation of the stomach with gas.—*J. J. McCort.*

Logue, Bruce R. Dissecting aneurysm of the aorta. *Am. J. M. Sc.*, July, 1943, *206*, 54–66.

Dissecting aneurysm of the aorta is a disease described as a splitting of the aorta in the media. The autopsy incidence was found to be 0.7 per cent in 1,519 autopsies from 1937 to 1940. In a study of the literature the author found that arteriosclerosis has invariably been present and it is believed that an intimal tear in an atheromatous area is the initial process.

Twelve cases that came to autopsy are presented. An antemortem diagnosis was made in 10 of the 12 cases observed and confirmed on necropsy.

The average age of the 12 patients was forty-five with a range of thirty-five to sixty-six. Ten of the 12 patients gave a history of previous cardiovascular symptoms. Eleven of the group either had hypertension on admission or gave a history of previous hypertension. The twelfth patient had a calcareous stenosis of the aortic valve.

Roentgen examination of the chest was made in 8 cases. Marked cardiac enlargement was noted in 6 instances and a moderate enlargement in 2 instances. There was a widening of the supracardiac shadow in 3 cases. A radiolucent area outside of the aorta and believed to be caused by the dissection was found in only 2 cases. A mediastinal effusion was evident in the roentgenogram of 1 patient and 1 other patient showed an extreme eccentric bulging of the heart to the right. This was due to an aneurysmal sac.

Tamponade was the cause of death in 7 cases. Hemorrhage into the pleural cavity, uremia, coronary occlusion and ventricular fibrillation were other causes of death.—*J. J. McCort.*

Weiss, Soma, Stead, Eugene A., Jr., Warren, James V., and Bailey, Orville T. Scleroderma heart disease; with a consideration of

certain other visceral manifestations of scleroderma. *Arch. Int. Med.*, June, 1943, *71*, 749–776.

The clinical histories of 9 patients with generalized scleroderma are reported. Postmortem examinations were performed on 2 patients. These 9 patients were selected for study because they all had symptoms and signs of heart disease. In 7 of the 9 cases the patients were women. Their ages at the onset of the cutaneous changes ranged from nineteen to sixty-two years, the average being thirty-eight years. In 3 cases the appearance of cardiac symptoms preceded changes in the skin by as much as two years. Also there were symptoms of Reynaud's disease in 8 of the 9 cases. The degree of blanching and pain in the extremities on exposure to cold could not be correlated with the progression of the visceral manifestations of the disease. Roentgen examination of the involved parts may show decalcification of bone or even loss of bony substance in the terminal phalanges and at times there may be calcified areas in the skin.

In 6 of the cases in which roentgen examination of the chest was done, strikingly similar changes were encountered. In all there was cardiac enlargement varying from a moderate to a marked degree. The heart was triangular in shape and in most cases the beat was of poor amplitude. In one instance the supracardiac area appeared to be widened and in another there was a prominent truncus pulmonaris. The roentgen findings did not suggest hypertensive or valvular heart disease. There was no detectable calcification in the valves. The left ventricle was not predominantly enlarged and the left auricle was not unduly prominent. A combination of the triangular shape and the weak heart suggested to the roentgenologist the diagnosis of myxodema heart disease or of pericardial effusion. In all of the roentgenograms there was an increase in the pulmonary markings, this usually being more marked in the lower lobe. In several cases the lungs showed a peculiar diffuse mottled or granular appearance, particularly at the bases and extending well out into the periphery but sparing the apices. At times the changes suggested to the roentgenologist the appearance of bronchiectasis or lipoid pneumonia. In instances of heart failure hilar congestion was usually noted. The focal areas of fibrosis in the lungs in 2 of the cases reported here may be related to the sclerodermatous process. It is difficult to rule out foci of chronic bronchopneumonia with organization, especially in view of the extensive lymphocytic infiltration and the peribronchial fibrosis in regions of normal alveoli. However, the distribution, corroborated by the results of roentgen examinations would be unusual in chronic bronchopneumonia.

The authors state that the lesions in the heart consist of scars of unusual type. These involve the myocardium, extending to the epicardium and endocardium only secondarily and then to a slight degree. There are certain resemblances between these lesions and those due to vascular changes. There are a number of ways, however, in which the lesions encountered postmortem in the hearts of the 2 patients with scleroderma differ from those caused by vascular disease. The lesions in the myocardium in patients with scleroderma were not in any particular relation to arteries, the structures being indifferently included in the scars or not. Furthermore the vessels were normal or showed minor intimal thickening without thrombosis or significant diminution in the caliber of the lumen. The hemosiderin deposits often seen in areas of myocardial scarring due to vascular lesions were entirely absent. Within the scars in the hearts of the 2 patients studied postmortem, the myocardial fibers were preserved in small numbers even in the center of the lesion. This was true also of fat cells and of blood vessels. The sequences were interpreted as a primary overgrowth of fibrous tissue with secondary destruction of other myocardial structures. The histopathologic nature of the lesion is different from the lesions of Fiedler's myocarditis, although their distribution is similar. The writers feel that the evidence points toward the interpretation that the myocardial lesions are an integral part of scleroderma. The pathologic observations, together with the clinical data in the cases of the series, indicated that sclerodermal heart disease is a clinical and pathologic entity.—*J. J. McCort.*

Smith, J. James, and Furth, Jacob. Fibrosis of the endocardium and the myocardium with mural thrombosis: notes on its relation to isolated (Fiedler's) myocarditis and to beriberi heart. *Arch. Int. Med.*, May, 1943, *71*, 602–619.

The authors encountered 3 cases in which

the patient died in the hospital of congestive failure of obscure origin. In all the cases the patients were carefully studied during life and examined postmortem. Clinically and pathologically these cases resemble each other closely, and without recourse to the clinical history the anatomical diagnosis might well have been isolated myocarditis. Review of the history, clinical course and histologic status, however, suggest the possibility that the changes might have been due to long continued dietary deficiency or defect in the absorption and utilization of certain acessory food factors.

Several teleroentgenograms including the anteroposterior and lateral views were made at a 2 meter distance in each case. In Case I the heart was tremendously enlarged and all diameters, particularly that of the left ventricle and the pulmonary artery, appeared full. A small amount of fluid obscured the left costophrenic angle. The heart in Case II was increased to the right and the left with a straightening of the left cardiac border, the left ventricle constituting the major enlargement. On roentgen examination of Case III the transverse diameter of the heart was increased, the enlargement being mainly left ventricular and the pulmonary artery was so prominent that mitral stenosis was suggested. Considerable fluid was apparent in the right pleural space with extension into the minor fissure.

The principal findings at necropsy in these cases agreed in several respects. In each there was evidence of cardiac failure with chronic passive congestion of the viscera. Pulmonary infarction was encountered in 2 cases while in the third there were small renal infarcts. The heart was enlarged in each case, weighing 650, 500 and 460 gm. respectively. Mural thrombi with varying degrees of organization were seen in both right and left ventricles in 2 cases, while the left ventricle alone was involved in the third. There was no anatomic evidence of valvular defects, hypertension, arteriosclerosis or syphilis. Myocardial fibrosis was the conspicuous microscopic change. The most marked feature in all cases was the widespread endocardial fibrosis in both right and left ventricles, varying in its extremes from plaque-like deposits to the formation of a dense fibrous tissue plaque covering the myocardium and investing the papillary muscles and trabeculae carneae.

The patients, 2 men and 1 woman, were thirty-five to forty years of age. In 1 case symptoms were present during eight years with the final phase of the illness occupying twelve months. In the other 2 cases the patients were ill for eight and nine months, respectively. In each there was progressive decline modified slightly by therapeutic measures. One patient, a Chinese man, had lived on a deficient diet over a long period: the other 2 patients had poor appetites and had taken diets probably border line in their content of the vitamin B complex. In all cases the diet was deficient after the onset of the final illness. Whether the cases here described actually represent chronic beriberi heart or at all the consequence of nutritional deficiency is not adequately proved. However, the question is raised whether these changes could have been associated with deficient diet and could represent a variant of beriberi heart.—*J. J. McCort.*

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Dr W. C. Röntgen

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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CHRONOLOGY OF RÖNTGEN'S LIFE*

By OTTO GLASSER, PH.D.
Cleveland Clinic Foundation
CLEVELAND, OHIO

1845—March 27—Born at 287 Poststrasse in Lennep, Rhine Province, Germany.
1848—May—Röntgen family moved to Apeldoorn, Holland.
1862—Dec. 27—Entered Utrecht Technical School, Holland
1865—Jan. 18—Entered University of Utrecht to audit courses as a student of mechanical engineering.
Nov. 16—Moved to Zürich, Switzerland as a student of mechanical engineering at the federal Polytechnical School.
1866—Met Anna Bertha Ludwig, who was born on April 22, 1839, in Schwamendingen, Switzerland.
1868—Aug. 6—Graduated as mechanical engineer from the Polytechnical School of Zürich, Switzerland.
1869—June 22—Received Ph.D. degree from the University of Zürich and became assistant to August Kundt, professor of physics.
1870—In the capacity of assistant, Röntgen followed Kundt to the Julius-Maximilian University at Würzburg.
1872—Jan. 19.—Married Anna Bertha Ludwig of Zürich in Apeldoorn, Holland.
Followed Kundt to the University of Strassburg as his assistant.
1873—Oct. 3—Röntgen's parents moved from Apeldoorn to Strassburg to live near their children.
1874—March 13—Became *Privat-dozent* in physics at the University of Strassburg.
1875—April 1—Became professor of physics and mathematics at the Agricultural Academy at Hohenheim in Württemberg.
1876—Oct. 1—Returned to the University of Strassburg as associate professor of theoretical physics.
1879—April 1—Became professor of physics at the Hessian Ludwigs-University in Giessen.
1884—June 21—Röntgen's father died at Giessen.
1886—Declined offer of chair of physics at the Friedrich-Schiller University of Jena.
1887—The Röntgens took Josephine Bertha, Mrs. Röntgen's six year old niece, into their home and adopted her when she was twenty-one.
1888—Declined offer of chair of physics at the University of Utrecht.
Aug. 8—Röntgen's mother died at Bad Nauheim.
Oct. 1—Became professor of physics at the Julius-Maximilian University in Würzburg.
1894—May—August Kundt died at his summer home near Lübeck.
June—Röntgen acquired an improved Lenard cathode-ray tube from Mül-

* From: Glasser, Otto. Dr. W. C. Röntgen. Charles C Thomas, Springfield, Illinois, 1945.

ler-Unkel in Braunschweig for experimental studies.
Became rector of the University of Würzburg.

1895—Feb.—Declined offer of chair of physics at the Albert-Ludwigs University in Freiburg i. Br.

Nov. 8—Röntgen discovered the first effects due to *A new kind of rays.*

Dec. 28—Submitted the manuscript of a paper *On a new kind of rays, a preliminary communication* to the secretary of the Würzburg Physical-Medical Society for publication in its *Sitzungsberichte.*

1896—Jan. 1—Sent reprints of his first communication and copies of his x-ray pictures to his colleagues Exner, Kohlrausch, Lummer, Poincaré, Schuster, Voller, Warburg, and Zehnder.

Jan. 4—Röntgen's first x-ray pictures were exhibited at the Physical Institute of Berlin University on the occasion of the fiftieth anniversary celebration of the Berlin Physical Society.

Jan. 5—First newspaper story of the discovery of x-rays appeared in the Vienna *Presse.*

Jan. 6—News of the discovery was cabled all over the world.

Jan. 13—Röntgen demonstrated the x-rays before Kaiser Wilhelm II and Kaiserin Victoria at the Berlin castle; he was decorated with the Prussian Order of the Crown, II class.

Jan. 23—Lectured on his discovery of x-rays before the Physical-Medical Society at the Physical Institute of the University of Würzburg.

Jan. 30—Declined to lecture before the German Reichstag and several scientific societies.

March 3—Honorary degree of Doctor of Medicine of the University of Würzburg.

March 9—Submitted the manuscript of his second communication, *On a new kind of rays, continued,* to the secretary of the Würzburg Physical-Medical Society.

March 10—Left for Sorrento to escape the flood of honors and invitations.

April 16—Honorary citizen, Lennep, Röntgen's birthplace.

April 20—Royal order of merit of the Bavarian Crown. This order carried with it personal nobility. Röntgen accepted the decoration but refused to accept nobility.

May—Corresponding member, Prussian Academy of Sciences, Berlin.

Nov.—Corresponding member, Bavarian Academy of Sciences, Munich.

Nov. 30—Rumford gold medal, Royal Society, London.
Baumgaertner prize, Vienna Academy.
Honorary member, Naturforscher-Gesellschaft, Freiburg i. Br.
Honorary member, Société Scientifique Antonio, Alz. Mexico.
Honorary member, Physical Society, Frankfort, o. M.
Honorary member, Chester Society of Natural Sciences.
Corresponding member, Société Nationale des Sciences et Mathématiques, Cherbourg.
Corresponding member, Wissenschaftliche Gesellschaft, Göttingen.

1897—March 10—Submitted his third communication, *Further observations on properties of x-rays,* to the Prussian Academy of Science, Berlin for publication in its *Sitzungsberichte.*
Elliot-Cresson medal, Franklin Institute, Philadelphia.
Prize Lacaze, Academie des Sciences, Paris.
Mattencei medal, Rome.
Honorary member, Swiss Naturforscher Gesellschaft.
Honorary member, Physical-Medical Society, Erlangen.
Honorary member, Röntgen Society, London.
Honorary member, Société des Médecines Russes, Petersburg.
Honorary member, Sociéte Impériale de Medicine, Constantinople.
Honorary member, Society of Former Students of Federal Polytechnical School, Zürich.
Corresponding member, Reale Accademia di Geographici, Florence.
Member, American Philosophical Society, Philadelphia.

1898—Prize, Otto-Wahlbruch-Stiftung, Hamburg.
Honorary member, New York Medical Society.
Corresponding member and bronze plaque, Reale Accademia dei Lincei, Rome.
Corresponding member, Reale Instituto Veneto di Scienze.
Nonresident member of the Société Hollandaise des Sciences, Harlem.

1899—Received offer of chair of physics at the University of Leipzig but declined.
Received the title of *Royal Geheimrat* from the Bavarian Government.
Diploma, University of Zürich.
Corresponding member, Cataafsch Genootschap, Rotterdam.
Nonresident member, Royal Academy of Sciences, Stockholm.

1900—April 1—Became professor of physics and director of the Physical Institute at the Ludwig-Maximilians University in Munich.
Grosskomturkreuz of the royal order of merit of the Bavarian Crown.
Order of merit of Saint Michael, I Class.
Silver medal of Prince Regent Luitpold.
Komtur of the order of the Italian Crown.
Member of the Maximilian order for sciences with decoration.
Barnard medal, Columbia University, New York.
Honorary member, German Academy for Phys. Diet. Therapy, Hamburg.
Honorary member, Society of Physicians, Munich.
Nonresident member, Academy of Medicine, Paris.
Member, Academy of Sciences, Munich.

1901—Nobel Prize in Physics, Stockholm.
Honorary member, Physical Society, Stockholm.

1902—Received invitation of Carnegie Institute in Washington to use its laboratory for special work but did not accept.
Honorary member, Institute de Coimbra.

1903—Honorary member, Philosophical Society, Cambridge.
Honorary member, Berlin Röntgen Society.
Corresponding member, Reale Accademia dei Science, Turin.

1904—Declined offer of presidency of Physikalisch-Technische Reichsanstalt in Berlin-Charlottenburg.
Honorary member, Society of Physicians, Vienna.
Röntgenstrasse, Cologne.

1905—March 27—Address of German physicists, Boltzmann, Braun, Drude, Ebert, Graetz, Kohlrausch, Lorentz, Planck, Riecke, Warburg, Wien, Wiener, Zehnder on the occasion of the tenth anniversary of the discovery of the roentgen rays, which was also Röntgen's sixtieth birthday; plaque at Physical Institute of University of Würzburg.
Honorary member, Society for the Encouragement of Arts, etc., London.
Honorary member, Medico-Chirurgical Society, Edinburgh.
Honorary member, German Röntgen Society.

1906—Folder, board of trustees, Deutsches Museum, Munich.
Honorary member, Royal Institution of Great Britain.

1907—Nonresident member, Societa Italiana delle Scienze, Rome.
Member, Royal Academy of Sciences, Amsterdam.

1908—Honorary member, Society of Physicians, Stockholm.
Honorary member, German Medical Society, New York.
Title of Excellency bestowed upon Röntgen by the Prince Regent of Bavaria.

1909—Röntgenstrasse, Würzburg.
Honorary citizen, Weilheim.

1910—Honorary member, German Society of Neurologists.
Honorary member, Berlin Medical Society.

1911—Röntgenstrasse, Halle.
Honorary member, Society of Physicians, Smolensk.
Order pour le Mérite for Science and Art.

1912—Declined offer of professorship at Prussian Academy of Sciences, Berlin.
Russian diploma, Odessa.
Planned to visit relatives in America.
Address, life membership Deutsches Museum, Munich.

1913—Honorary member, German Surgical Society.
Honorary member, Swiss Röntgen Society.

1914—Honorary member, New York Röntgen Society.

1915—March 27—Röntgen spent his seventieth birthday quietly with his best friend, Boveri, who was seriously ill in Oberstdorf, Bavaria; on the next day he had an audience with the King of Bavaria in Munich.
Addresses and honors on the occasion of Röntgen's seventieth birthday:
Würzburg Medical Faculty.
Röntgen Foundation.
University of Giessen.
Philosophical Faculty, University of Würzburg.
Physikalisch-Technische Reichsanstalt.
University of Strassburg.
Annalen der Physik.
Röntgenstrasse, Munich.
Iron Cross, II Class.

1918—Honorary degree of doctor of engineering, Technical High School, Munich.

1919—June 22—Fiftieth anniversary of Röntgen's doctorate in philosophy. He received the following honors:
Fiftieth doctorate diploma, University of Zürich.
Address of Prussian Academy of Sciences, Berlin.
Helmholtz medal in bronze.
Helmholtz medal in gold.

1920—Honorary member, German Physical Society.
Röntgen retired from the University of Munich and became professor emeritus.
March 27—Röntgen's seventy-fifth birthday. He received the following honors:
Honorary degree of Doctor of Natural Sciences, Johann Wolfgang Goethe University, Frankfort a. M.
Honorary member, Bonn Röntgen Society.
Honorary member, Frankfort Röntgen Society.
Honorary member, Society for Natur and Heilkunde, Dresden.
Commemorative tablet placed on the house of Röntgen's birth and an address by the mayor of the city of Lennep.
Nonresident member, Prussian Academy of Sciences, Berlin.
Nonresident honorary member, Vienna Academy of Sciences.
Member, Strassburg Scientific Society, Heidelberg.
Röntgenstrasse, Lennep.
Röntgenstrasse, Weilheim.
Honorary citizen, Würzburg.

1921—Honorary member, Society and Friends of the Friedrich-Wilhelm University of Bonn.
Honorary member, Nordisk Forening f. med. Radiologi.
Honorary academician, University of Bonn.
Corresponding member, Phys. Okonom Society.

1922—Commemorative tablet placed on the house Röntgen lived in during his Zürich college years, Swiss Röntgen Society.

1923—Feb. 10—Röntgen died at Munich.
Nov. 10—Röntgen's ashes were put to rest in the family grave at [illegible]

1928—July 27—Röntgen bust, sculptured by Georgii, unveiled at the University of Munich.
Dec. [illegible]—Röntgen Memorial Room opened at the Physical Institute, University of Würzburg.

1930—Nov. [illegible]—Röntgen monument [illegible] in Lennep.
Röntgen-Realschule [illegible], Lennep.

1932—June [illegible]—Röntgen Museum [illegible] Lennep.

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SCIENTIFIC FOREFATHERS OF RÖNTGEN

By OTTO GLASSER, Ph.D.
Cleveland Clinic Foundation
CLEVELAND, OHIO

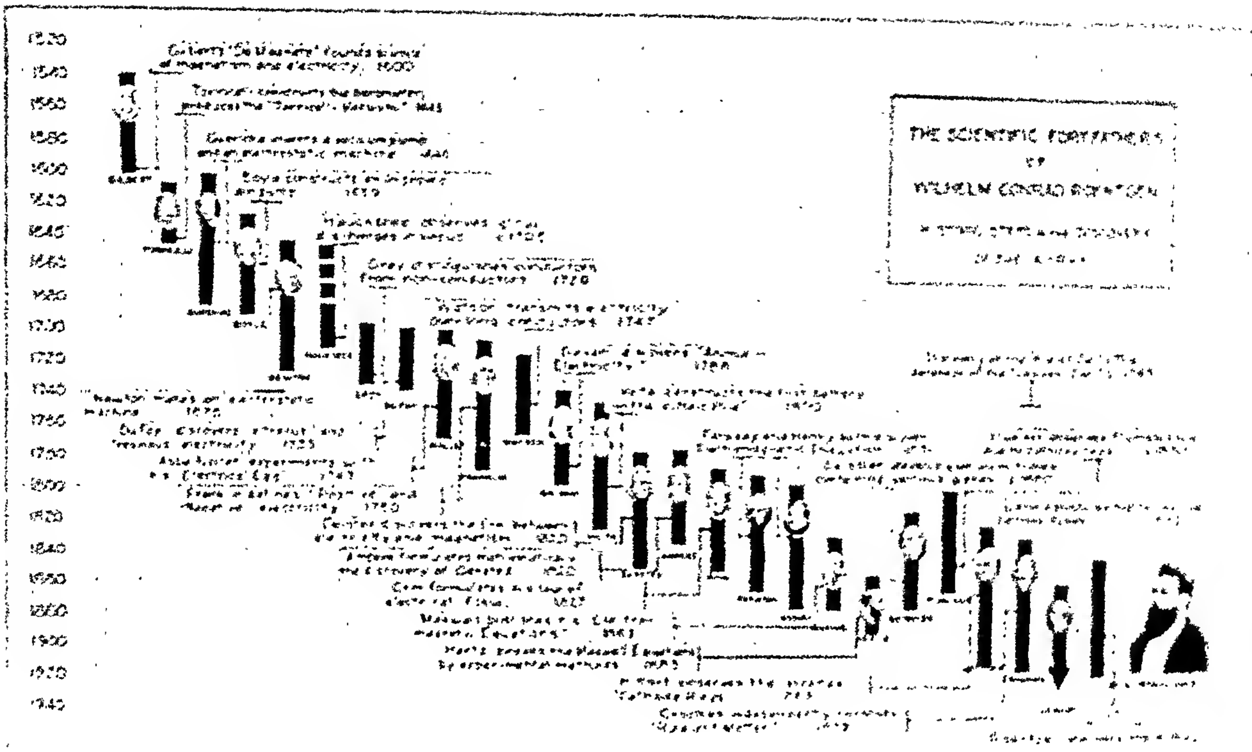
JOSEPH PRIESTLEY, the British scientist who sought refuge in the United States in 1794, was the originator of an interesting Chart of Biography. According to his own description[1] this chart "represents the Interval of Time between the Year 1200 before Christ, and 1800 after Christ, divided, by an equal Scale, into Centuries. It contains about two thousand Names of Persons the most distinguished in the Annals of Fame; and the Length of their Lives is represented in it by Lines drawn in proportion to their real Duration, and placed so as to show, by Inspection, how long any number of Persons were contemporary, and how long one Life began before, or extended beyond another, with every other Circumstance which depends upon the Length of Lives, and the relation they bear, both to one another, and to Universal Time; Certainty being always represented by full lines, and Uncertainty by Dots, or broken Lines."

Several years ago, in collaboration with Leopold Rovner, I applied Priestley's ingenious method to a historical evaluation of scientific men whose work led up to the discovery of the roentgen rays (see figure). The chart was first shown in the scientific exhibit at the eighteenth annual meeting of the Radiological Society of North America in Atlantic City in 1932. A more comprehensive treatise was published under the title "Genealogy of the Roentgen Rays."[2]

The ordinate of the chart represents a time interval from 1520 to 1940, subdivided into intervals of twenty years; the abscissae are evenly spaced intervals for twenty-six selected scientists. The time of birth, life span, and time of death of each is indicated by a vertical black line placed chronologically upon the time scale indicated on the ordinate. Two life spans are incomplete: that of Hauksbee, whose year of birth is unknown, and that of Lenard, who was alive at the time of the completion of the chart. It is immediately evident that some life spans are very short, such as those of Torricelli or Hertz, while others are very long, such as those of Guericke, Newton, Franklin, Volta, Henry, Hittorf, and Crookes.

The chart offers ample evidence of the usefulness of this type of presentation. A conventional presentation of the data contained in the figure probably demonstrates this fact better by comparison than any further description.

1540–1603 Gilbert
1603 Gilbert's "De Magnete" founds science of magnetism and electricity
1608–1647 Torricelli
1643 Torricelli constructs the barometer, produces the "Torricellian vacuum"
1602–1686 Guericke
1646 Guericke invents a vacuum pump and an electrostatic machine
1627–1691 Boyle
1659 Boyle constructs an improved air pump
1642–1727 Newton
1675 Newton makes an electrostatic machine
? –1713(?) Hauksbee
1705 Hauksbee observes glow discharges in vacuo
1696–1736 Grey
1729 Grey distinguishes conductors from non-conductors
1698–1739 Du Fay
1733 Du Fay discovers vitreous and resinous electricity
1700–1770 Nollet
1749 Abbé Nollet experiments with his "electric egg"
1706–1790 Franklin
1750 Franklin defines positive and negative electricity



The original multicolored chart measures 2½ by 3½ feet. The name of each scientist is inserted immediately beneath his life line; his portrait, if available, is superimposed upon the life line. The most important contribution of each scientist is dated and points to the year when it was made. Since the chart was compiled more reliable data have been found which have been incorporated in the tabulation.

1715–1787 Watson
1747 Watson transmits electricity over long conductors

1737–1798 Galvani
1786 Galvani discovers "animal electricity"

1745–1827 Volta
1800 Volta constructs the first battery, the "Voltaic pile"

1777–1851 Örsted
1820 Örsted discovers the link between electricity and magnetism

1775–1836 Ampère
1820 Ampère formulates mathematically the discovery of Örsted

1787–1854 Ohm
1827 Ohm formulates his law of electrical flow

1791–1867 Faraday
1831 Faraday and Henry both discover electromagnetic induction

1797–1878 Henry (see Faraday)

1831–1879 Maxwell
1873 Maxwell publishes his "electromagnetic equations"

1857–1894 Hertz
1887 Hertz proves the Maxwell [illegible] by experimental methods

1814–1879 Geissler
1860 Geissler develops vacuum tubes containing various gases

1801–1868 Plücker
1859 Plücker observes fluorescence due to cathode rays

1824–1914 Hittorf
1869 Hittorf observes the straight cathode rays

1832–1919 Crookes
1879 Crookes independently observes radiant matter

1862– Lenard
1892 Lenard produces [illegible] cathode tube

1845–1923 Röntgen
1895 Röntgen discovers the X rays

REFERENCES

1. [illegible]

2. [illegible]

POST-WAR VISIT TO RÖNTGEN'S LABORATORY

By LIEUTENANT COLONEL LEWIS E. ETTER
Medical Reserve Corps, United States Army

ONE of my first thoughts on being assigned to duty with the Army of Occupation in Germany was to wonder about the present condition of Würzburg and particularly of Röntgen's Laboratory in the Physical Institute of the University of Würzburg. After looking at endless scenes of demolition and devastation of the cities in northwestern Germany, I was fearful of what might have befallen the scene of Röntgen's classical experiments. From the days of my earliest association with radiology, I was attracted to the character of the great physicist, and having read his notable biography by Glasser,[1] my desire to see the spot where he worked had been greatly enhanced. So, in September of this year when the opportunity was afforded, all personnel of our department* set out for that town in Bavaria, made famous by the great discovery of just fifty years ago.†

No doubt the same question as to the present condition of Röntgen's Laboratory has occurred to many radiologists and it is to answer them that this account is given.

As we arrived in the environs of Würzburg our apprehension mounted, for even in the suburbs bomb destruction was seen everywhere. As we journeyed on into the city we met with rubble-strewn streets and, it being a warm day, with the stench of death from those buried in the ruins. We were directed to the University, and as we rode on our anxiety mounted. What was pointed out to us as the University was broken walls, stark chimneys and empty windows. But among all the ruins miraculously stood the Physical Institute, intact, except for some loose slate, plaster and broken windows (Fig. 1). A high explosive aerial bomb apparently directed at the main railroad station early in March,

Fig. 1*a*. View of one end of the Physical Institute of the University of Würzburg showing the plaque commemorating Röntgen's discovery. NA means "not ausgang" or way out from the air raid shelter in the basement.

[1] Glasser, Otto. Wilhelm Conrad Röntgen und die Geschichte der Röntgenstrahlen. Julius Springer, Berlin, 1931. Also, Wilhelm Conrad Röntgen and the Early History of the Roentgen Rays. Charles C Thomas, Springfield, Illinois, 1934.

* X-Ray Department, 115th General Hospital, United States Army.

† A later visit was made to Remscheid-Lennep, the town between Düsseldorf and Cologne where Röntgen was born one hundred years ago (on March 27, 1945). Even though Lennep is situated in the western industrial heart of Germany (the Ruhr) which was subjected to most severe bombing, the town was spared almost completely. The house where Röntgen was born and the other one containing the Röntgen museum sustained not the slightest damage. These buildings look exactly today as pictured in Glasser's biography although the back portion of the museum has been considerably enlarged. Here there is a remarkable collection of Röntgeniana and a display of roentgen-ray equipment arranged chronologically from the first tubes used to the latest perfected machines, including a working model of the roentgen cinematograph designed by Prof. Dr. Janker of Bonn. To date there have been some 20,000 visitors from all over the world to the museum, which is well worth a long trip to see.

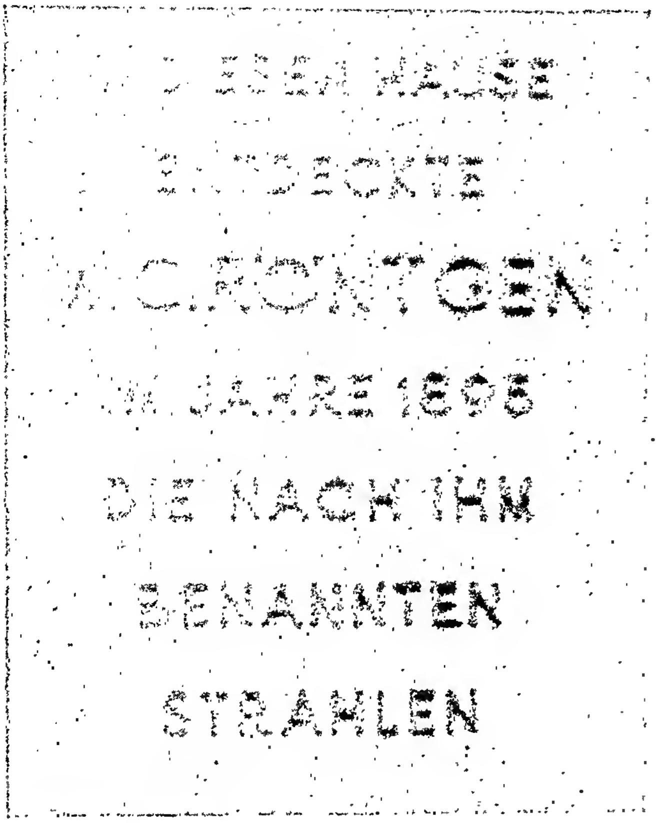


Fig. 1*b*. Close-up of plaque translated to read: "In this house in the year 1895 W. C. Röntgen discovered the rays which were named after him."

1945, landed in the park across from the Institute and blew out all the windows and doors. During the main attack on the city in the night of March 16, some 240,000 incendiary bombs were dropped during twenty minutes and, within three hours, nearly all of the city was burned. About two hundred high explosive bombs followed and one completely wrecked the Anatomy Institute, two buildings removed, with a blast that loosened much of the slate on the Physical Institute. Only three incendiary bombs touched this building and each was extinguished before much damage resulted. Unharmed, on the side of the building, was the plaque translated to read, "In this house in the year 1895

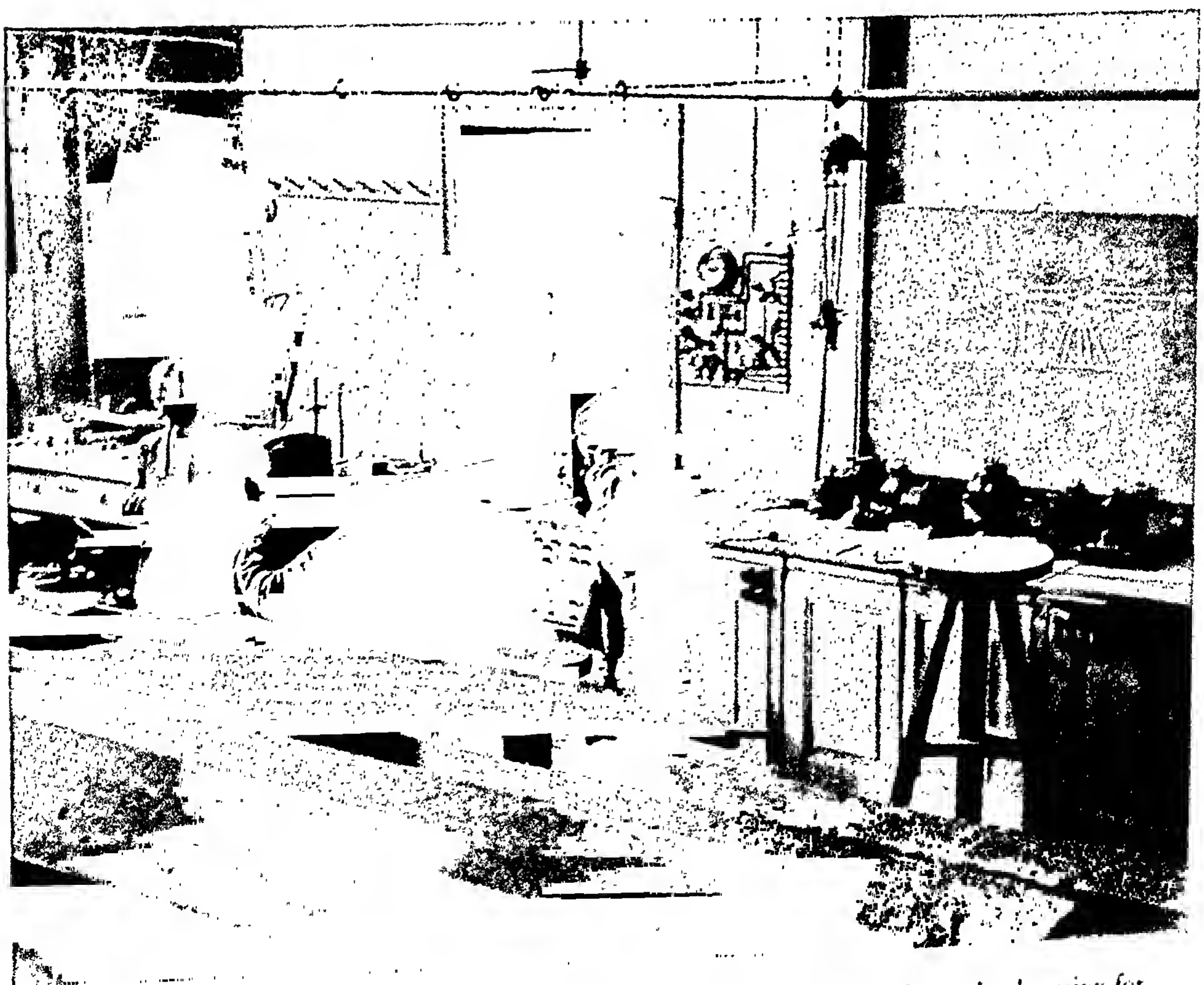


Fig. 2. View in lecture room of the Physical Institute used during the last school session for instruction of students in the University of Würzburg. (Thanks are due T/4 Paul Walkup for the use of this photograph.)

W. C. Röntgen discovered the rays which were named after him."

At the door we were welcomed by the present Professor of Physics* and his assistants who very kindly showed us all through the building. They too could hardly believe the providential sparing of their Institute when all else—to use the expressive German word—was kaputt. of our conquering armies since it stood in a corner of the room in plain view when the soldiers went through. All that protected it was a sign attached to it in English written by the Germans saying, "This is the gun which Röntgen first photographed with his rays. If taken, please take it with care and precaution as it is a museum piece."

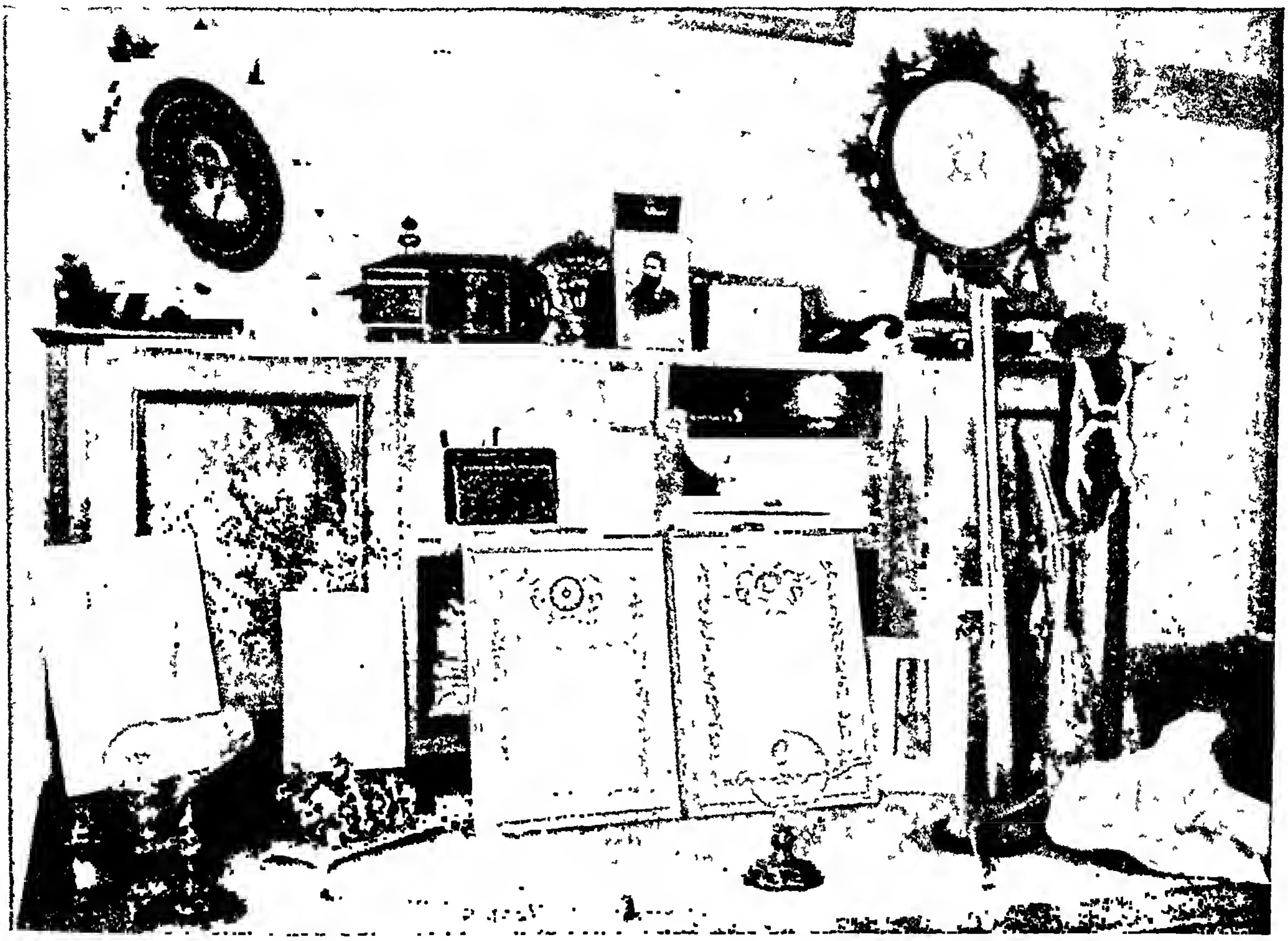


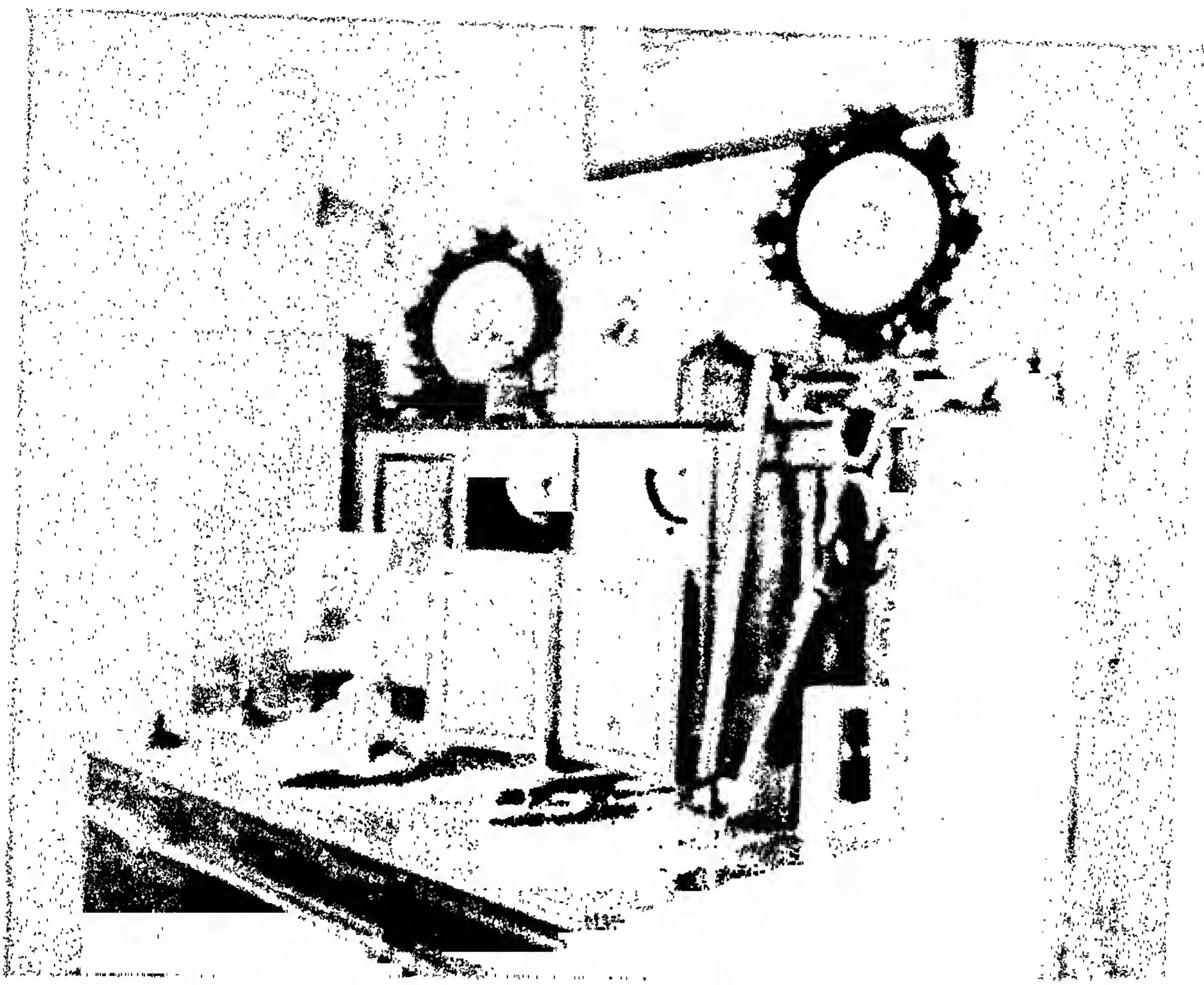
Fig. 3*a*. View of Röntgen's desk and mementoes: Roentgenogram of von Kolliker's hand and that of Röntgen's wife; Cambridge Society medal; Nobel Prize diploma; gun stock and barrel of gun; roentgenogram of barrel of gun; Crookes, Lenard, Hittorf and "absolute vacuum" tubes; death mask of Röntgen's hands; photographs of Röntgen and of his mother and father.

They were engaged in making what minor repairs they could, where glass and other materials were available, and in returning to their proper places the historical collection and other things which had been placed in the basement for safe keeping. A remarkable fact was that Röntgen's gun was not picked up as a souvenir by soldiers

The rooms where Röntgen had worked were still in use and were said to be in much the same condition as he left them. The lecture hall where he delivered his memorable report on "Über eine neue Art von Strahlen"† on January 23, 1896, before the Physical and Medical Association of Würzburg, was still being used for instruction of students of physics at the University. A view of the blackboard and demonstra-

* Prof. Dr. Friedrich Harms, Director of the Physical Institute; Prof. Dr. Heinrich Ott, Associate Professor of Physics; Dozent Dr. Karl Gailer, Assistant Professor of Physics.

† "About a new kind of rays."



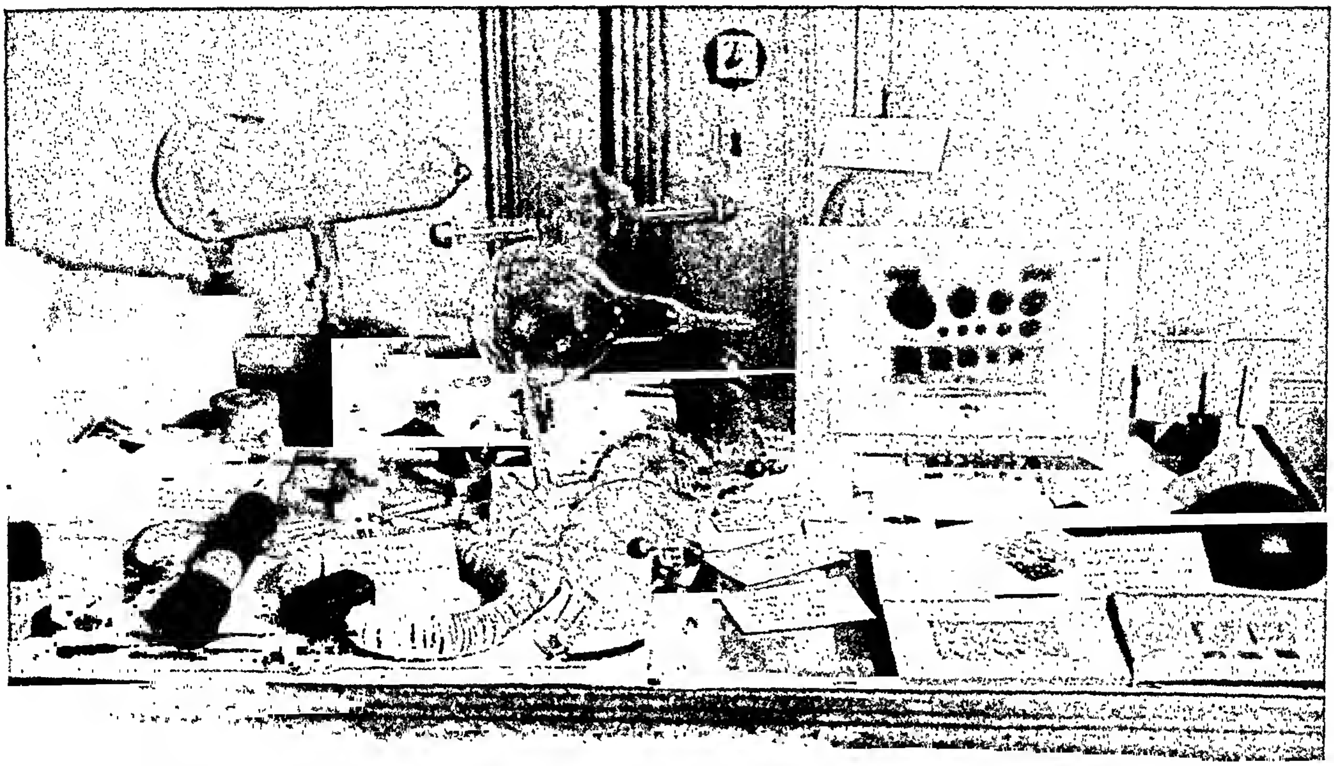


Fig. 3c. Here shown are Crookes tube, left background, several Hittorf tubes in center, glass jar for ionization of air with print of box of weights standing against it; prisms along right edge with masks of lead and aluminum in right foreground. In left foreground at very edge an "absolute evacuated" tube (Röntgen used many of these) with electromagnet beside it.

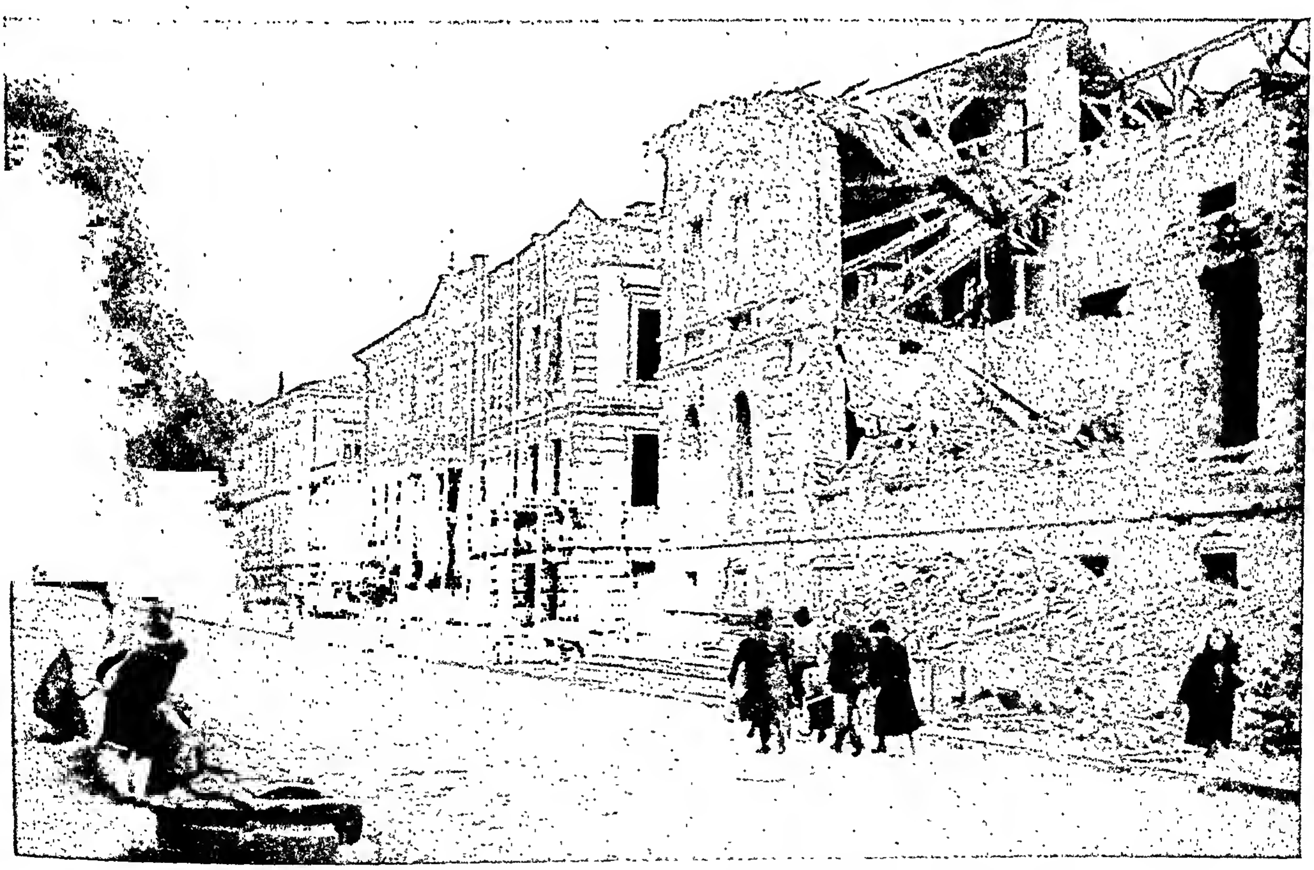


Fig. 4. University of Würzburg showing from left to right: Physical Institute, Physiological Institute, Anatomy Institute.

dows cut out for measuring absorption by various metals (Fig. 3*c*). Also preserved in the room were his Alpine attire and staff, fishing and hunting equipment, as well as many stereoscopic views of scenes he had visited, attesting to his interest in these avocations.

Today Würzburg, with its crumbled ruins, stands as an example of the vengeance wreaked on Nazi Germany because of its intolerable doctrines, while safe and unscathed the mementoes of Röntgen rest securely in the Physical Institute. This will be welcome news to many, especially to those whose dreams for the future have included a plan for a pilgrimage to this shrine of Roentgenology.

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G. FAILLA
Caldwell Lecturer, 1945

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PROTECTION AGAINST HIGH ENERGY ROENTGEN RAYS

CALDWELL LECTURE 1945*

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NEW YORK, NEW YORK

I. INTRODUCTION

THE problem of protection is an appropriate one to discuss in a Caldwell Lecture, for the great pioneer, Eugene Wilson Caldwell, in whose honor the Lecture has been established by the American Roentgen Ray Society, died at the height of his career as a result of overexposure to roentgen rays. Also, Caldwell was an engineer before he became interested in medicine and the protection problem in its practical applications is essentially an engineering one.

At the expense of untold suffering and early demise of many such pioneers, radiologists soon became aware of the insidious nature and seriousness of roentgen-ray hazards. The problem of protection, therefore, has been studied for many years and a large body of useful knowledge has accumulated. Today the means of protection can be provided readily but the utilization of these means is not always carried out effectively. In the ultimate analysis the human element is always present—and as ever unpredictable in individual instances. The occurrence of roentgen-ray injuries cannot be eliminated completely, but by persistent effort the frequency can be greatly reduced.

During the war period, a great extension of the use of roentgen rays in industry has taken place. Roentgenography of materials bids fair to compete with medical roentgenography in volume of work. Higher and higher voltages are demanded in this field. There are at present only a few so-called supervoltage machines (1 million volts or over) used for therapeutic purposes, whereas more than seventy are in operation in industrial plants. Two million volt machines are now commercially available. Twenty million and even 100 million volt roentgen generators have been built and used. The rapid increase in the number (and power) of roentgen-ray installations makes protection a matter of considerable social significance. Safety codes are now being formulated under the auspices of the American Standards Association. Wisely it was decided to make these codes applicable only to industrial roentgen-ray installations, where conditions are quite different from those obtaining in the medical field. However, these codes may—and probably will—form the basis for regulatory codes relating to radiological installations.

The work in connection with the above mentioned codes has brought to the fore certain gaps in quantitative experimental data needed for the most satisfactory solution of protection problems. With the available information we can at present provide adequate protection in installations operating at voltages up to 1 million and even 2 million. We do this not by exact calculations but by the use of more or less empirical relations and estimates based on past experience. Accordingly it is always necessary to introduce a factor of safety. If, upon completion of an installation, dosage rate measurements are made and it is found that the safety factor used was too large, the cost of the protective barriers was higher than necessary. If the measurements reveal insufficient protection, the cost and inconvenience of alterations are out of proportion to the initial cost. This economical aspect of the problem becomes more important with increase in voltage.

* Caldwell Lecture to have been given before the American Roentgen Ray Society at the 1945 meeting which was canceled.

In the present paper no attempt is made to fill the gaps in the available technical data. If anything, they are made more prominent. The object of the paper is twofold: (1) to present a simple method for the solution of protection problems, so far as the mathematical steps are concerned; (2) to suggest a method for the determination of absorption curves of more direct application to the protection problem, especially in the high energy range. The interaction of radiation and matter and the interpretation of absorption curves are discussed somewhat at length since they are of fundamental importance. Finally, some interesting problems of measurement, peculiar to very high energy roentgen rays (20 to 100 million volts) are touched upon.

2. SOLUTION OF PROTECTION PROBLEMS IN TERMS OF THE HALF-VALUE LAYER

Given a source of radiation, we may protect ourselves by staying at a long distance therefrom or by interposing a sufficiently thick absorbing barrier between the source and our bodies. Let us assume that the dosage rate at 1 meter from the source is 1 r/min. To determine accurately the distance at which the dosage rate is 12.5 mr/hr.*—the permissible value for continued daily exposure of the whole body—it is necessary in general to take into account the interaction of roentgen rays and matter in the radiation field (air, ground and neighboring objects) even when no solid barrier is in the path of the direct rays. However, for the moment we shall neglect the influence of matter present in the radiation field and, therefore, we may calculate the desired distance on the basis of the inverse square law alone. It is $x = \sqrt{\frac{60,000}{12.5}} = 69.3$ meters. Having neglected the influence of matter on the dosage rate, this distance is independent of the quality of radiation. It applies to any (point) source of roentgen rays producing a dosage rate of 1 r/min. at a distance of 1 m.

The second part of the problem is to calculate the thickness of the protective barrier necessary to reduce the dosage rate to 12.5 mr/hr. at a given distance (shorter than 69.3 m.). This will depend on the quality of radiation and the kind of absorbing material used. However, the calculation may be made in two steps, of which one is independent of both quality of radiation and kind of material.

It is obvious that the dosage rate at the point in question may be reduced to one-half its initial value by interposing between the two a suitable absorbing barrier of a certain definite thickness. This is called the half-value layer (hvl). We shall assume for the moment that interposing a second barrier of the same material and thickness again reduces the dosage rate by one-half, which therefore becomes one-fourth of the initial value. Addition of a third half-value layer reduces the dosage rate to one-eighth of the initial value, and so forth.

Returning to the example, we may now ask: How many half-value layers are required to reduce the dosage rate from 1 r/min. to 12.5 mr/hr.? The reduction factor is $60,000/12.5 = 4,800$. Therefore, the required number, n, of half-value layers is $2^n = 4,800$ or $n = 12.2$. Obviously, this number is independent of the quality of radiation and the kind of material of which the barrier is made. To determine the actual thickness of the barrier it is necessary to know also the numerical value of the half-value layer for the quality of radiation and kind of material in question. Thus, if in the above example the half-value layer is 1 mm. of lead, the barrier must be 12.2 mm. thick to reduce the dosage rate to 12.5 mr/hr. at a distance of 1 meter from the source.

In practice protection is generally brought about by a suitable combination of distance and barrier. We shall assume for convenience that the radiation output of the machine is expressed in roentgens per minute at a distance of one meter. Let

* It is becoming common practice in the art of radiation protection to express doses and dosage rates in terms of a smaller unit than the roentgen. A convenient subunit is the milliroentgen of which one thousand equal one roentgen (1,000 mr = 1 r and 12.5 mr/hr. = 0.0125 r/hr.).

R_1 represent this dosage rate. At any other distance x meters, the dosage rate will be $R_x = R_1/x^2$ r/min. If R_1/x^2 is greater than 12.5 mr/hr. (0.000208 r/min.) a protective barrier must be provided. Following the procedure outlined above, we may express the thickness of the barrier in terms of the number n of the appropriate half-value layer

$$2^n = \frac{R_1}{0.000208x^2} = \frac{4800R_1}{x^2}$$

$$n = 12.2 + 3.32 \log R_1 - 6.65 \log x \cdots . \quad (1)$$

The physical interpretation of the above equation facilitates the solution of protection problems. It is obvious that when the radiation output is doubled, the thickness of the protective barrier must be increased by 1 half-value layer; when it is quadrupled, 2 half-value layers must be added, and so on. The mathematical relation between the number n_R of additional half-value layers and dosage rate R_1 is

$$n_R = 3.32 \log R_1 \cdots . \quad (2)$$

Similarly when the distance is increased, the thickness of the protective barrier may be reduced by a number n_x of half-value layers given by the expression

$$n_x = 6.65 \log x \cdots . \quad (3)$$

Comparing the three equations it will be seen now that the total number of half-value layers required in a protective barrier consists of three parts: (a) A constant number (12.2) which is necessary to reduce the dosage rate at 1 meter distance from 1 r/min. to 12.5 mr/hr. (b) The number which must be added if the dosage rate at 1 meter is greater than 1 r/min. (or subtracted if less). (c) The number which must be subtracted if the distance is greater than 1 meter. In terms of half-value layer, therefore, the problem is reduced to one of algebraic addition instead of multiplication and division. This makes possible its solution by simple graphical means.

The simplest scheme is, perhaps, to take care of each part of the problem separately. This can be done by means of the first two sets of scales in Figure 1. An example will illustrate their use. Determine the thickness of the necessary barrier, in terms of half-value layers, when the roentgen-ray output is 90 r/min. at 1 meter and the region to be protected is at a distance of 8 meters from the target—protection being based on the permissible dosage rate of 12.5 mr/hr. From scales *A–B* it will be seen that the number of half-value layers for a roentgen-ray output of 90 r/min. at 1 meter is 6.5. Similarly from scales *C–D* it is found that for a distance of 8 meters the number of half-value layers to be subtracted is 6. Therefore, the total number n required is (eq. 1)

$$n = 12.2 + 6.5 - 6$$
$$= 12.7 \text{ hvl.}$$

It will be recalled that with an output of 1 r/min. at 1 meter, the distance required to reduce the dosage rate to 12.5 mr/hr. is 69.3 meters. Since this is a longer distance than is usually encountered in practical problems, the constant term (12.2 hvl) and the distance term (6.65 log x) may be combined as shown in scales *E–F*. For the appropriate distance on scale *E* we then read directly on scale *F* the difference between 12.2 and the distance term. Solving the same problem by means of these scales we find on scale *F* that 6.2 hvl are required when the distance on scale *E* is 8 meters. This is equal to 12.2–6 in eq. (1) as previously found. The output term is determined by means of scales *A* and *B* as before.

In planning roentgen-ray protection it is always safest to assume continuous operation of the machine. This has been done in the above example. However, sometimes this is not done and allowance is made for the time that the machine is in actual operation in the course of an eight hour day. If in the above example we assume that the machine operates not more than four hours a day, we may solve the problem by taking for the roentgen-ray output a proportionately lower value, that is, 45 r/min. at 1

meter. Then from scales A–B we find that the required number of half-value layers for this output is 5.5 and the total number is now 11.7 instead of 12.7. Incidentally, this result brings out how little is gained by taking into account the time during which the machine is not in operation. Limiting the running time to one-half of the eight hour problem in reverse. In an existing installation it is found that the operator is at a distance of 8 meters from the target. The intervening barrier is 11.7 hvl thick. The output of the machine is 90 r/min. at 1 meter. How many hours during an eight hour working day can the machine be run, without exposing the operator to more than 0.1

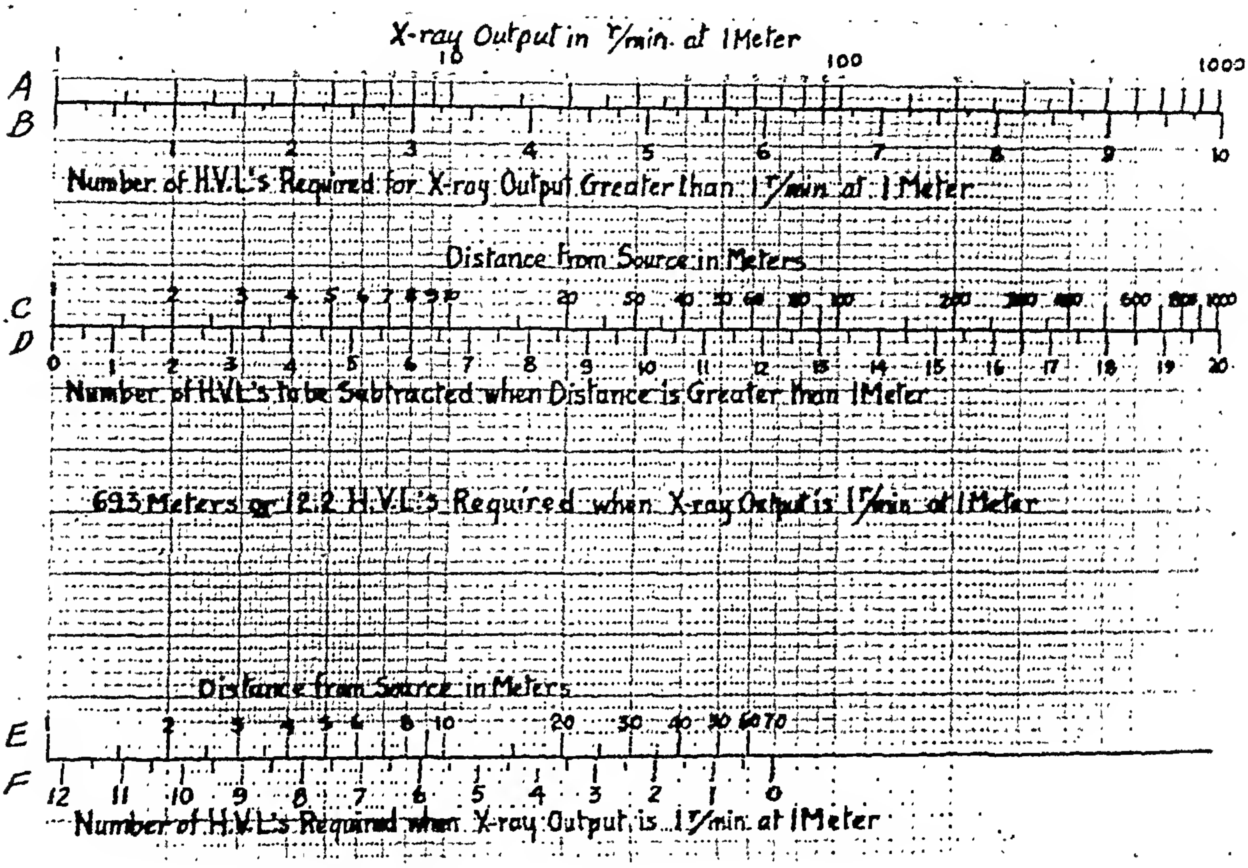


Fig. 1

working day reduces the thickness of the protective barrier by 1 half-value layer which in this case is less than 10 per cent of the total. Once the barrier has been installed the limitation on the operating time remains. Subsequent additions to the protective barrier always cost more. Whenever the question comes up in practice all factors should be considered carefully. Sometimes, in special cases, it is advantageous to take into account the actual running time of the equipment and the degree of occupancy of the regions to be protected.

The scales of Figure 1, of course, may be used to solve other problems. To give another illustration we shall solve the above per day? From scales E–F we find that the constant term and distance term combined require 6.2 hvl for a distance of 8 meters. Therefore, $11.7-6.2=5.5$ hvl of the barrier remain to take care of the output term. From scales A and B we find that 5.5 hvl correspond to an output of 45 r/min. at 1 meter. With this output the dosage rate in the protected region is 12.5 mr/hr. Since the actual output is 90 r/min, at 1 meter, the dosage rate in the protected region is 25 mr/hr., and therefore the operator is exposed to the permissible daily dose of 0.1 r in four hours of actual operation of the machine.

It should be noted that the scales of

Figure 1 are independent of the unit of distance used, provided the output is expressed in r/min. at *unit* distance. To illustrate this point we shall solve the above example in terms of feet. The output of 90 r/min. at 1 meter corresponds to 970 r/min. at 1 ft. The 8 meter distance equals 26.3 ft. We shall use scales *E–F* as if scale *E* had been graduated in feet. At the 26.3 point on scale E we obtain 2.8 hvl on scale *F*. At the 970 point on scale *A* we read 9.9 hvl on scale *B*. While the two terms are quite different, their sum, $2.8+9.9=12.7$, is the same as before.

In practice it is customary to state the output of a roentgen-ray machine in r/min. at a point in the center of the *useful* beam at a "standard" distance from the target. In roentgen therapy this distance is usually 50 cm.; in industrial roentgenography it is 1 meter. As indicated above, the latter is more convenient for the present purpose. However, it is important to note that the roentgen-ray output to use in designing protective barriers is not necessarily that in the direction of the useful beam. The same thing applies to the half-value layer. This point is not important in dealing with ordinary roentgen rays because there is little difference in intensity and quality with respect to angle; and, also, because protective barriers are not expensive. In the supervoltage region and beyond, however, it is economically worth while to take advantage of the non-uniformity in angular distribution of the emitted radiation, as regards both intensity and quality. When the roentgen tube is fixed in position, or its angulation is limited, some of the necessary barriers may well be designed on the basis of the lower output and lower penetrating power of the radiation in certain directions. In such cases, the dosage rate at 1 meter (as well as the half-value layer) to be used in connection with Figure 1 is that in the direction under consideration and not that of the useful beam.

In this connection another advantage of the half-value layer scheme of solving protection problems may be pointed out. If the radiation output in r/min. at 1 meter is known in all directions around the target for the unshielded roentgen tube, one may determine the total number of half-value layers required in any direction to protect personnel from the direct radiation. This number of half-value layers may then be provided partly by a lead enclosure around the tube and partly by a lead lined or concrete wall. Or, similarly, the number of half-value layers embodied in the tube shield may be subtracted from the total number required to obtain the number of half-value layers that the protective barrier must provide. It should not be forgotten in this connection that a separate allowance must be made for scattered radiation that may reach the wall. We are now considering only protection against direct radiation emitted at the target.

Certain useful relations derived from the scales of Figure 1 may well be mentioned at this point. It will be noted by inspection of scales *A–B* that a factor of 10 corresponds to 3.32 hvl ($10=2^{3.32}$); a factor of 100 to 6.65 hvl; and a factor of 1000 to 9.97 or practically 10 hvl. This relation is particularly useful in determining the half-value layer from an absorption curve plotted on a semilogarithmic scale. If the straight line portion of the curve covers three cycles, it is only necessary to read the difference in the thickness of absorbing material for the three cycle span and to divide this by 10 to obtain the half-value layer. Having determined the half-value layer one may calculate the absorption coefficient from the relation $\mu=0.693/\text{hvl}$. For a one cycle span the dividing factor is 3.32, etc.

Comparison of the two sets of scales *A–B* and *C–D* reveals that for the same numerical value on scales *A* and *C*, the number of half-value layers on scale *D* is just double that on scale *B*.* Accordingly only one set of scales *A–B* is necessary for the solution of the problem. The output term of equation (1) is determined by reading the number of half-value layers directly on scale *B*.

* This is obvious to those familiar with logarithms.

The distance term is obtained by using scales A–B and doubling the number of half-value layers. With this in mind attention may be called to the fact that the ordinary polyphase slide rule has two scales like A and B in Figure 1. The scale corresponding to A is the 3-cycle log scale used constructed. The chart of Figure 2 serves the same purpose. To illustrate its use the solution of the typical problem given as an example before is indicated on the chart by arrows.

In developing the half-value layer method just described it was assumed that inter-

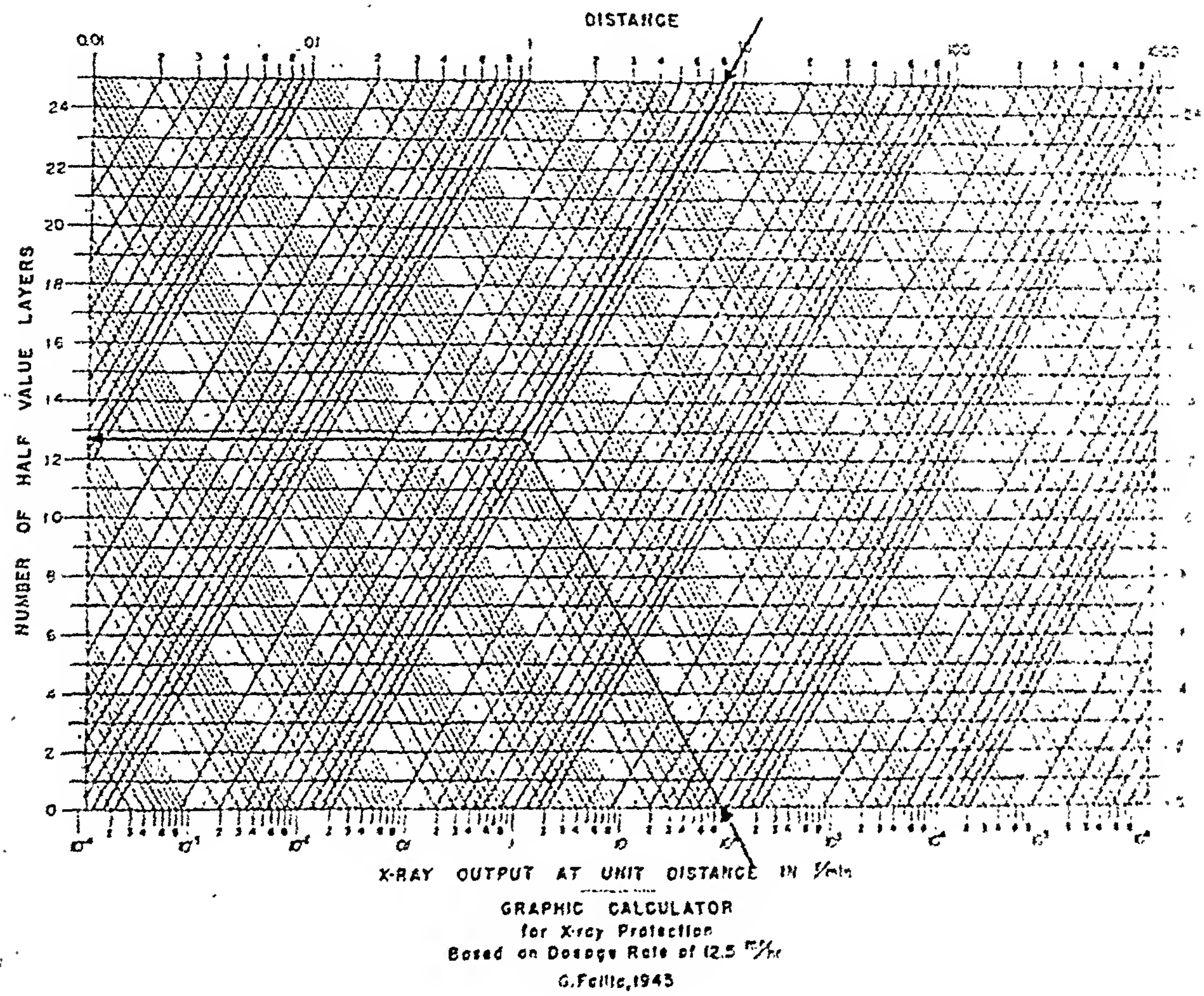


Fig. 2

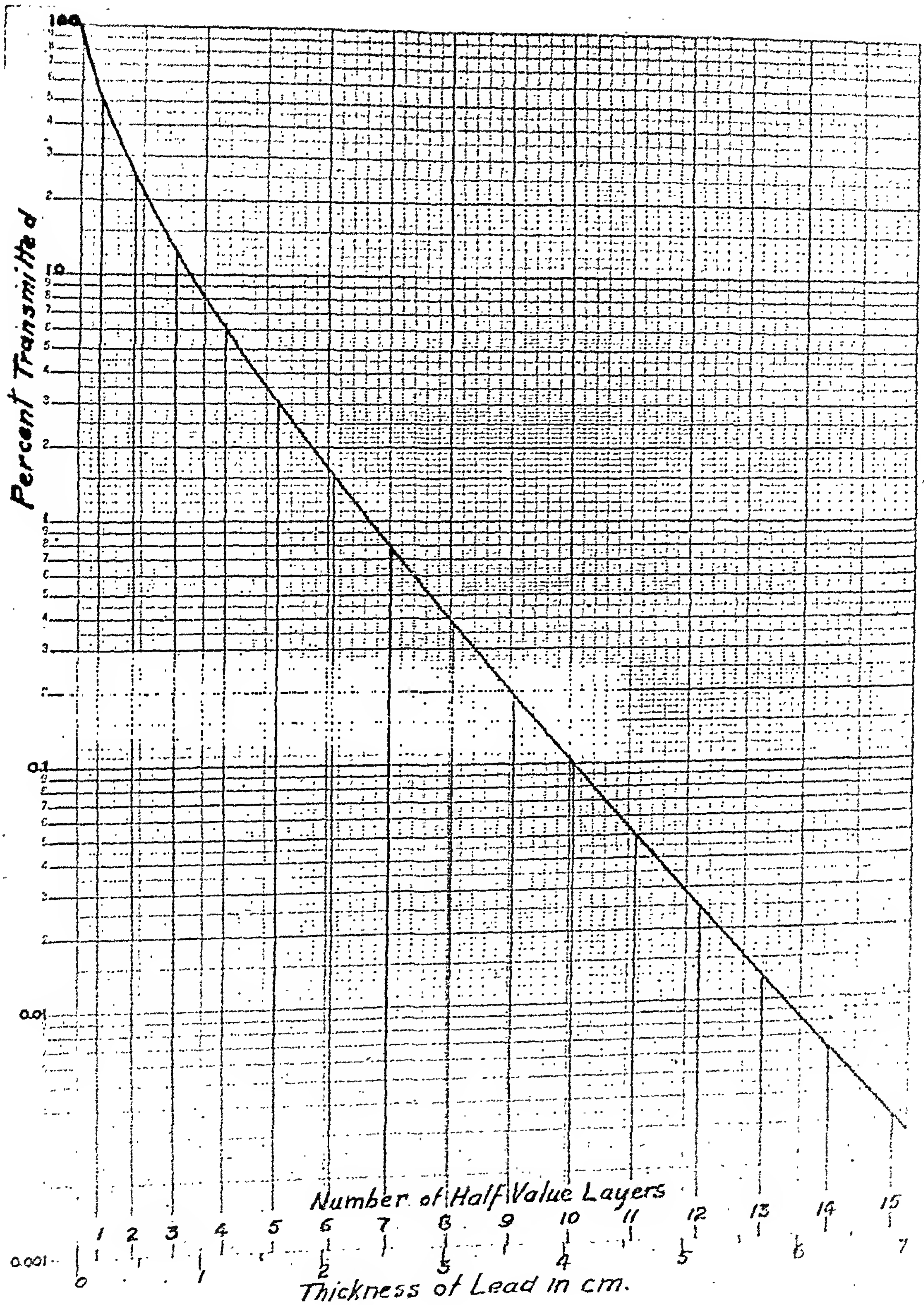
to determine the cube of a *number*. The scale corresponding to B is the linear scale on the reverse of the slider used to determine the logarithm of a number. This scale on the slide rule is slightly shorter than it should be to correspond exactly to scale B of Figure 1. However, the difference is only 0.24 of 1 per cent and may be neglected. Accordingly, protection problems may be solved (in two steps) by the half-value layer method described here, without constructing special scales. To solve the problem in one step a special slide rule may be posing a second barrier of equal thickness to the first (1 hvl) the dosage rate would again be reduced by one-half. In other words, it was assumed that the half-value layer has a constant value throughout. In practice this seldom occurs and, therefore, having determined the number of half-value layers needed, we cannot compute the actual thickness of the barrier by simple multiplication. The difficulty is more apparent than real, for, in order to design a barrier by any method we must have, directly or indirectly, the following information

mation: (1) the radiation output of the machine in roentgens per unit time at some convenient distance (1 meter) in the direction in which the barrier is located; (2) the rate at which unit thickness of the barrier decreases the dosage rate, in the given direction, as the thickness of the barrier is increased. This means an "absorption curve" of a particular type, as we shall see presently. Assuming, however, that we have the appropriate absorption curve, the solution of the problem is simple, as may be seen from Figure 3. To the absorption curve, plotted in the customary way on semilog paper, is added a half-value layer scale parallel to the thickness scale. Construction of the half-value layer scale is indicated by the parallel vertical lines stemming from successive 50 per cent points on the curve. If then the calculated number of half-value layers is counted on the half-value layer scale, the corresponding thickness of material may be read on the thickness scale. The absorption curve is used only for the construction of the half-value layer scale and need not be shown in conjunction with the two parallel scales. This procedure presupposes, of course, that the thickness scale of the absorption curve is long enough to include the largest number of half-value layers that may be needed in the design of any barrier for the quality of radiation represented by the curve. This should always be the case for reasons discussed later. If a complete curve is not available, the primary data are insufficient to solve the problem accurately by any method. As an approximation the curve may be extrapolated in a reasonable way. It may be well to mention explicitly at this point an additional condition that the absorption curve must meet. The zero thickness point must correspond to the conditions under which the radiation output was determined; otherwise the output value used in the calculations and the absorption curve are not properly related to each other.

3. ABSORPTION CURVES

In the preceding section, the half-value layer was defined in effect as the thickness of a barrier of any given material such that, when interposed between the source and a given point, it reduces the dosage rate at that point to one-half its initial value. This implies that absorption measurements should be made under the conditions obtaining in any given case. Furthermore, since the dosage rate should be expressed in roentgens per unit time, the measurements should be made with instruments that fulfill the requirements imposed by the definition of the roentgen. Ordinarily absorption measurements are made for a different purpose and the results, in general, are not directly applicable to our problem. Little attention has been paid to this problem in the past because in the voltage range up to 200 or 300 kv. the distinction is of little practical importance. With the more common use of very high voltage roentgen rays the problem assumes greater proportions and it behooves us to examine the situation more closely.

In general, roentgen rays passing through a sheet of matter undergo the following changes: (1) Some are absorbed through the photoelectric process; (2) some are merely deviated from their path without change of wavelength; (3) some are scattered through the Compton process imparting some of their energy to electrons and then proceeding in new directions with increased wavelength; (4) some are transformed into pairs of electrons and positrons endowed with kinetic energy in addition to their mass equivalent energy when the energy of the pair creating photon is in excess of 1,022 kev. These are the primary reactions. It is evident that in going through the absorber the photons produced in the primary reactions will undergo similar changes. Furthermore, some of the resulting high energy electrons will produce roentgen rays. The positrons soon combine with electrons and disappear—are "annihilated"—producing photons of equivalent total energy. The passage of roentgen rays *through a thick layer of matter is therefore* a very complicated process. Especially in



Percent Transmitted
100
10
1
0.1
0.01
0.001
Number of Half Value Layers
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0 1 2 3 4 5 6 7
Thickness of Lead in cm.

Fig. 3

the case of high energy roentgen rays and a material of low atomic number the proportion of energy actually absorbed by the sheet of matter is small. Most of it either passes through unaffected or emerges from the material after undergoing certain transformations. In roentgen-ray protection, of course, any radiation that emerges from a barrier is potentially dangerous and must be taken into account. Hence it is of the utmost importance to realize that the usual absorption measurements made in the laboratory are not directly applicable to the protection problem, because scattered and secondary radiations of all kinds are intentionally prevented from reaching the measuring device.*

The experimental setup used for the determination of absorption coefficients is generally as shown diagrammatically in Figure 4.† The beam traversing the absorbing material A is small in cross-section and is delimited by the diaphragm D_1 (which should be of sufficient thickness to stop practically all radiation outside the beam from reaching the absorbing material A). Diaphragm D_2 is provided to allow a very small beam of the transmitted radiation to enter the ionization chamber C. Under these conditions practically all scattered and secondary radiation originating in A is prevented from entering the ionization chamber. Under these conditions and in the case of monochromatic roentgen rays the mathematical relation between the intensity‡ of the transmitted radiation I and thickness of absorber t is

$$I = I_0 e^{-\mu t}$$

where I_0 = intensity of radiation when no absorber is present

μ = "linear absorption coefficient," or, simply, absorption coefficient

A vast amount of work has been done during the last thirty years to determine the coefficients of absorption for different wavelengths and different materials. Numerical values are given in manuals and books on roentgen rays dealing with the subject. In the supervoltage region and beyond, actual measurements have been few but theoretical calculations are more valid, and reliable values of the absorption coefficients for monochromatic radiation are available up to many millions of volts. However, the point we wish to emphasize here is that whether obtained by measurement or calculation, the absorption coefficient generally given in tables is not the proper one to use in determining the thickness of a protective barrier. As already pointed out, in experiments planned to determine the absorption coefficient, it is desired to exclude from the transmitted radiation all scattered and secondary radiation originating in the absorber. The ab-

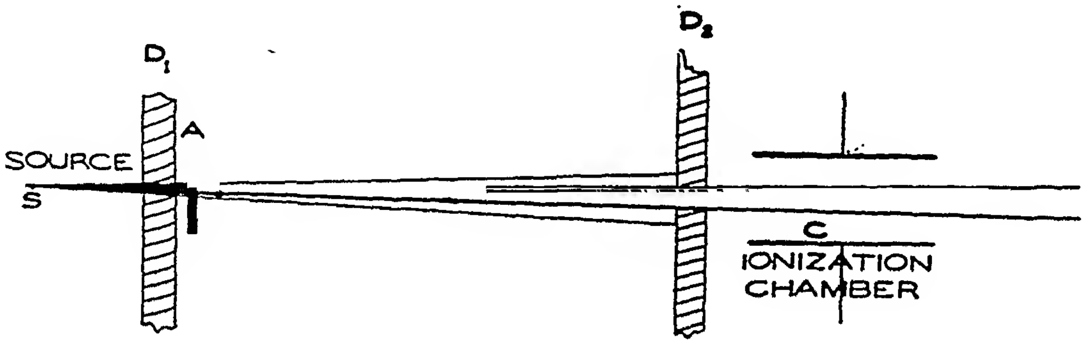


Fig. 4

* The intent is always there but the attainment of this desideratum is not always realized. This is one of the factors accountable for the discrepancies existing in published values of absorption coefficients.

† When monochromatic roentgen rays are used the source in the position shown is not the focal spot of the roentgen tube. This is irrelevant to the present discussion.

‡ Intensity = energy flux per unit area. In the case under consideration, by assumption, the quality of the radiation passing through the ionization chamber is always the same and therefore the ionization chamber reading is proportional to the intensity of radiation. (See later.)

sorption coefficient, as ordinarily defined, is in reality an attenuation coefficient. The transmitted radiation as measured is less intense (that is, has been attenuated) not only because the layer of matter has transformed some of the energy of the beam into something other than ionizing radiation, but also because some ionizing radiation of the original beam and most of that originating in the absorber is deviated out of the narrow beam entering the ionization chamber.

The relative importance of the different processes by which a narrow beam of roentgen rays is attenuated depends on the wavelength of the radiation and the nature of the material traversed. The coefficient μ may be broken down into separate components each referring to a specific process.

$$\mu=\tau+\sigma_s+\sigma_a+\sigma_p{}^*$$

where τ refers to the photoelectric process

σ_s refers to attenuation caused by transfer of energy to the photon in the Compton scattering process

σ_a refers to attenuation caused by transfer of energy to the electron in the Compton scattering process

σ_p refers to the pair formation process

In discussing the relative values of these coefficients, the different wavelength regions may be expressed to advantage in terms of the corresponding photon energies given by the formula:

$$\text{kev.}=\frac{12.4}{\lambda}$$

where λ = wavelength in Ångströms
and kev. = photon energy expressed in electron kilovolts or kilo-electron-volts.

For convenience, the term kilovolts is often used in this connection instead of electron kilovolts. The term mega-electron-volts, mev., or million electron volts, has found wide acceptance among physicists, and in conformity with this notation, it is well to use the term kilo-electron-volts, kev. In this paper kev. is used only to express the photon energy in the case of monochromatic radiation. The term kv. is used to indicate the maximum voltage applied to a roentgen tube. Thus 200 kv. roentgen rays are those produced in a tube to which a (peak) voltage of 200 kv. is applied. Only a small percentage of the emitted photons have an energy of 200 kev., the others have less energy. It is well to remember therefore that 200 kev. roentgen rays are much more penetrating than 200 kv. roentgen rays in this notation.

Returning to the discussion of the absorption coefficient, we shall point out first that the photoelectric component τ predominates over all others in the case of low voltage roentgen rays and high atomic number elements. For lead τ is large up to 500 kev.. and appreciable even at 2,000 kev. (2 mev.) For aluminum it is large only up to about 50 kev. The two Compton components $\sigma_s+\sigma_a$ for the same two materials predominate beyond the energy limits just given until pair formation becomes important. The latter occurs at energies higher than 5 mev. for lead and 15 mev. for aluminum. In Figures 5 and 6 it may be seen at a glance how the relative contributions of the three different components vary with photon energy in two extreme cases: lead and air. The solid curves represent the sum of the three components, that is μ. It is interesting to note that for lead μ has a minimum value at about 3.5 mev. This means that as the energy of the radiation increases up to 3.5 mev. lead becomes more "transparent." With further increase in energy, however, it becomes again less transparent.

At least in the photon energy region in which the Compton effect predominates, it is evident that "absorption" consists largely of deviation of radiation out of the

* The term referring to the simple scattering process without change of wavelength is omitted since it is negligible in the wavelength region of present interest (in which the wavelength is short in comparison to the dimensions of the atom).

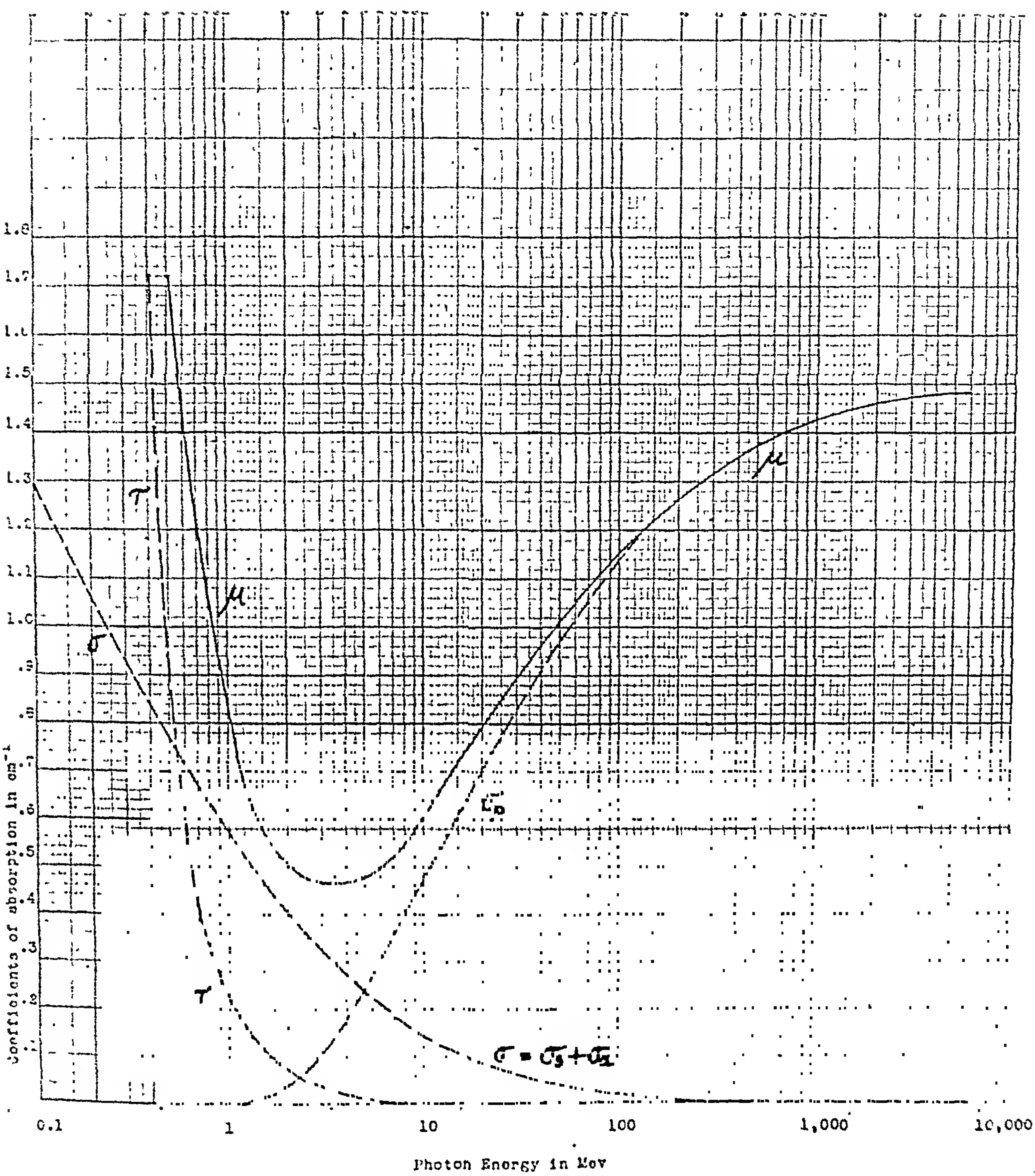


Fig. 5

narrow beam entering the measuring device. Actual absorption of energy by the material occurs through the absorption of the secondary electrons produced in the interaction of radiation and matter. In the case of the photoelectric effect all the energy of the primary photon is transferred to an electron. However, this process takes place only with electrons that are strongly bound and the kinetic energy of the electron after leaving the atom is less than that imparted to it by the photon. The balance of the energy reappears in the form of radiation as soon as another electron fills the place in the atom left vacant by the ejected photoelectron. For the K level in the lead atom the energy that reappears in the form of a photon amounts to 87 kev., and is therefore quite penetrating. This fluorescent radiation is emitted in all directions.

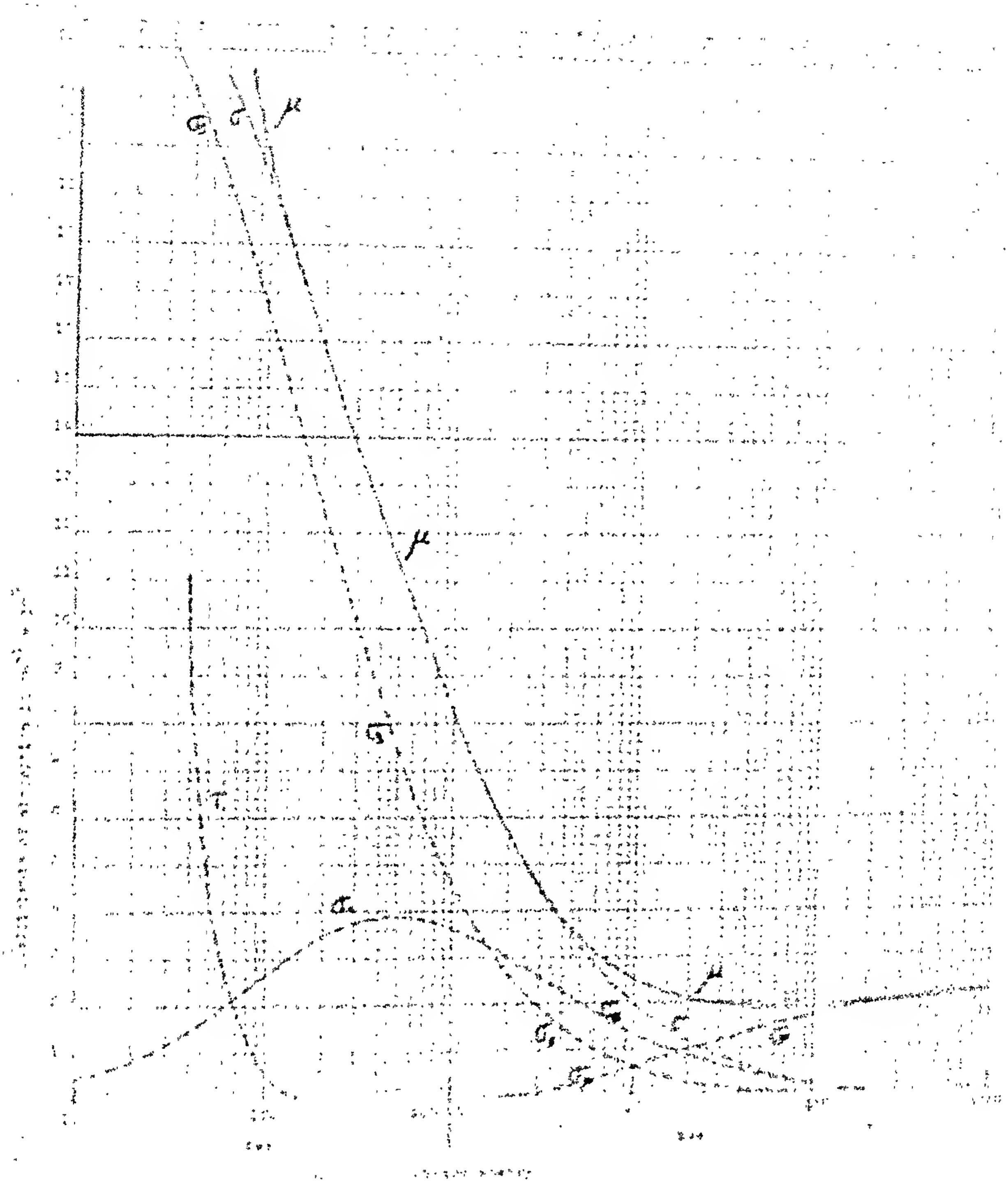


Fig. [illegible]

In the case of the Compton effect σ_a represents the fraction of the primary photon energy transmitted to the electron and σ_s the fraction imparted to the secondary photon. The relation between the two varies with the energy of the primary photon. In the low energy range σ_s is greater than σ_a. The two are equal when the photon energy is [illegible] and both decrease [illegible] at higher energies. [illegible] scattered photon [illegible]

the forward direction [illegible] process [illegible]

In the pair [illegible] of the [illegible]

is not large, this kinetic energy is absorbed by the material more or less *in situ*. When it is very large, much of it is transformed into photons. It is interesting to note that at energies much beyond the 3.5 mev. point (for which the absorption coefficient in lead is a minimum) some of the photons thus produced, and some Compton photons for that matter, may be more penetrating *in lead* than the original photons. In this region, also, the energy exchange from electrons to photons, or the reverse, takes place largely in the forward direction. The positron of the pair may be annihilated while it still possesses considerable kinetic energy, but more often it is annihilated after it has stopped. In general two photons, each of 511 kev. energy and traveling in opposite directions, are produced in this process.

From the foregoing, two things are evident: (1) the interaction of photonic radiation and matter gives rise to other photonic radiation; (2) the "secondary" photons have less energy than the primary ones. Now in discussing the experimental setup of Figure 4 it was stated that the aperture of the second diaphragm D_2 should be small enough to prevent any secondary or scattered radiation from entering the ionization chamber. In practice this condition becomes more difficult to meet as the energy of the radiation increases. As the thickness of the absorber becomes large (at high voltages) the beam spreads out considerably by "forward" scattering and a relatively large volume of the material can send radiation through the limiting diaphragm of the chamber. Furthermore, since in the parallel plate type of chamber, ions are collected from a much larger air volume than that actually traversed by the beam, any unwanted radiation passing through the diaphragm is apt to register. For the same reason (large ion collecting volume) the limiting diaphragm D_2 must be much thicker than the maximum thickness of absorber used, in terms of equivalent absorption. At any rate, some secondary and scattered radiation does enter the chamber. Since the energy of these photons is lower (or the wavelength longer) the ionization chamber reading is, in general, not proportional to the intensity of radiation. Actually, in practice, instead of the parallel plate chamber of Figure 4, a closed chamber of some sort would be used in the high energy range. The relation between ionization chamber reading and intensity of radiation is then more complex.

Inasmuch as for protection purposes we wish to measure radiation in roentgens, we shall assume that the small closed chamber is constructed of air equivalent materials. Also we shall assume that the wall thickness is equal to the range of the highest energy secondary electrons. We shall consider first the voltage range in which pair formation is negligible. The ionization in the chamber is due to that part of the energy abstracted from the beam of radiation that is capable of producing ionization *in situ*. This means the secondary electrons produced by the photoelectric and Compton process in air.* In the notation of the absorption coefficient μ, τ represents the fraction of the energy removed from the beam by the photoelectric process. In air the binding energy of the K electrons is small, and therefore substantially all the energy imparted to the electron is available to produce ionization. In the Compton effect, the portion of the energy transferred to the electron is represented by σ_a. Therefore, $\tau+\sigma_a$ represents the fraction of the energy of the radiation beam responsible for the ionization. If I is the energy flux per unit area, the ionization current in the air chamber will be

$$(i.c.) = CI(\tau+\sigma_a)_A$$

where C = a constant
and $(\tau+\sigma_a)_A$ refers to air.

So long as the wavelength of the radiation entering the chamber remains the same $(\tau+\sigma_a)_A$ is constant and the ionization current is strictly proportional to the intensity

* The wall is air equivalent by assumption.

of radiation (energy flux per unit area). In this case the exponential law of absorption may be put in terms of the ionization current

$$(i.c.)_t = (i.c.)_0 e^{-\mu t}.$$

We have found, however, that in practice, the quality of the radiation reaching the chamber is altered by the admixture of scattered and secondary radiation produced in the absorbing material in various ways. Accordingly, the relation between ionization current and thickness of absorber should not be exponential on the basis of a change in quality *per se*, without even considering the increase in the energy flux reaching the chamber caused by the secondary and scattered radiation. In practice the latter is more important, as we shall see presently.

In Figure 7 are plotted the values of τ, σ_a and $\tau+\sigma_a$ for air for different photon energies from 40 kev. to 10 mev. The values of σ_a are derived from the Klein-Nishina formula, which has been found to be quite reliable. The values of τ are difficult to obtain in that no satisfactory theoretical relation with wavelength has been worked out. The values in the table have been derived by graphical means from published tables of absorption coefficients and other information in the literature. The experimental data available are numerous but not very concordant, and the accuracy of the derived value of τ suffers from this fact. This, however, has little influence on the conclusion we wish to draw, namely, that since $(\tau+\sigma_a)_A$ (Fig. 7) remains between 3 and 4 $\times 10^{-5}$ cm.$^{-1}$ in the energy range of 100 to 2,000 kev., the quality effect on the relation between ionization current and energy flux through the chamber is not very marked in this range. If softer radiation (energy less than 100 kev.) reaches the chamber the

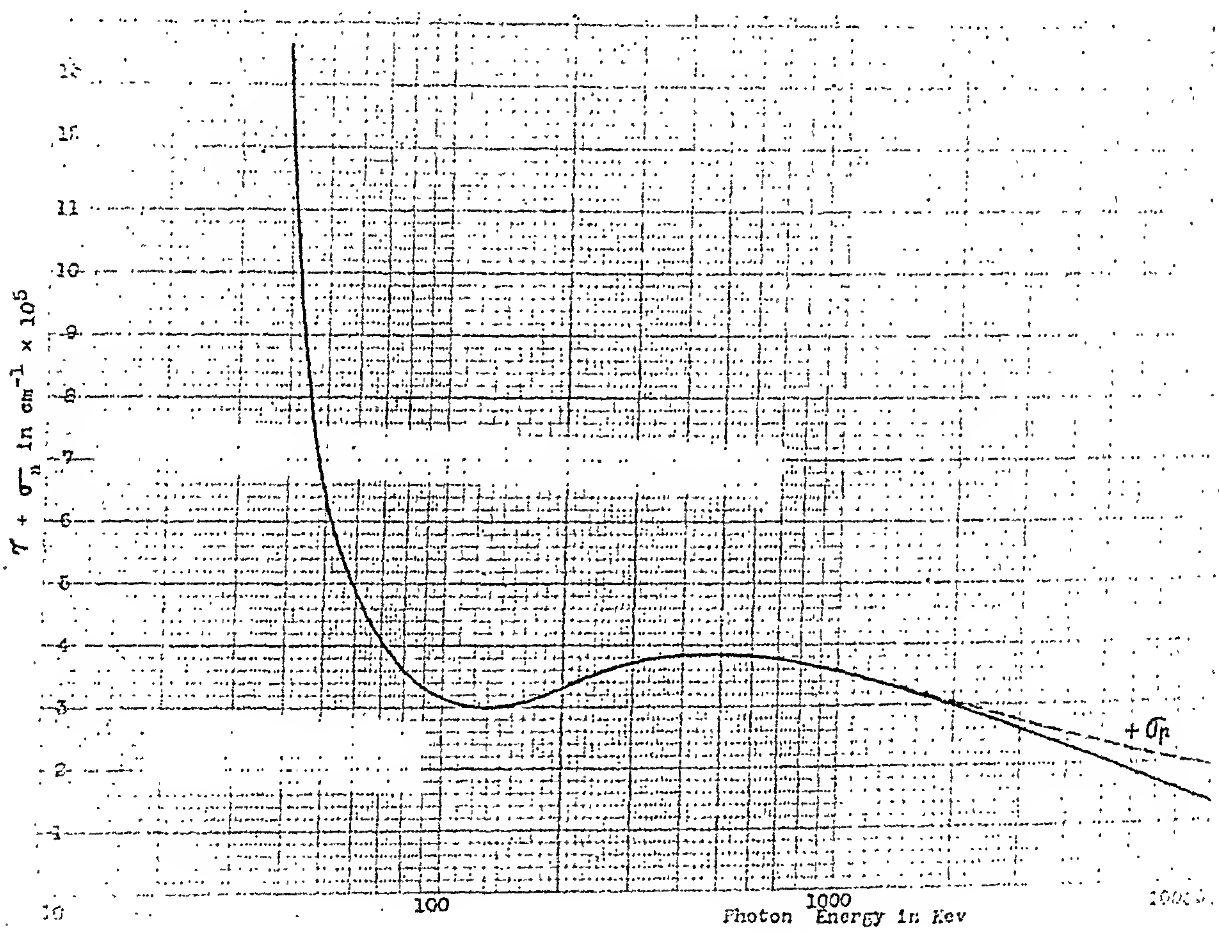


Fig. 7

effect may be considerable in proportion to the relative amount of such radiation with respect to the primary and the difference in the values of $(\tau+\sigma_a)_A$.

We shall now consider the influence of the energy flux contributed by the scattered radiation. It is obvious that the ionization chamber reading will be higher than it would be otherwise. It is also obvious that the amount of scattered radiation reaching the chamber must depend on the thickness of the absorber, other things being equal. In accordance with the processes of attenuation previously described—largely the Compton effect, in the present case—more and more of the primary radiation is scattered as the thickness of the absorber increases. However, since the wavelength is longer, this radiation is attenuated more readily by the material in which it is produced, and therefore the amount emerging from the absorber cannot increase indefinitely. Beyond a certain thickness an additional layer of the material adds as much scattered radiation as it prevents from coming out and the relative proportions between directly transmitted radiation and scattered radiation remain constant. The "absorption" curve plotted on semilog paper would be of the form shown in Figure 8 (*a*). The mathematical relation would be

$$I=I_0e^{-\mu(t-t_e)}$$

where t_e = the thickness of absorber indicated in the figure. It is the thickness necessary to bring the scattered and secondary radiation "in equilibrium" with the primary radiation, and may be called the equilibrium thickness. The value of μ obtained from this curve is the same as it would have been if no scattered radiation had been allowed to reach the ionization chamber. This is because the experimental conditions were assumed to be such that beyond a certain thickness of material the relative proportions of directly transmitted radiation and scattered radiation remained constant. (In addition, we are now considering only monochromatic radiation.)

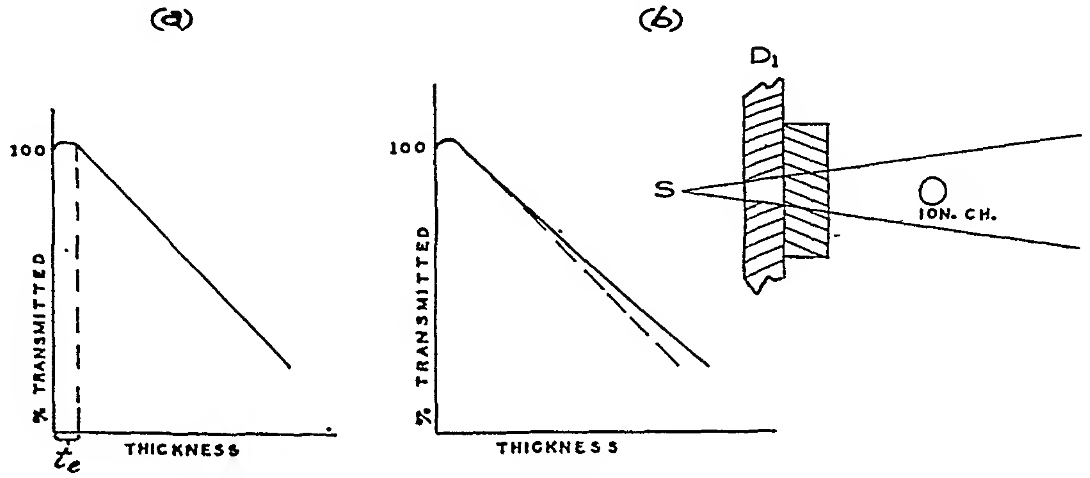


Fig. 8

When the proportion of scattered radiation reaching the chamber changes with the thickness of the material the absorption curve is not a straight line. This is illustrated in Figure 8 (*b*). Here the thickness of the absorber is about one-half of the distance between the diaphragm and the chamber. The last layer of absorber, therefore, is much closer to the chamber than the first, and contributes more scattered radiation to the chamber. If the radiation in case (*b*) is of the same wavelength as in (*a*), the absorption curve will differ from the straight line of (*a*) in the manner shown approximately in (*b*). The radiation, although monochromatic, does not give a straight line absorption curve on a semilog plot, and μ appears to vary with the thickness of the absorber. Experimentally the influence of this effect may be checked readily by taking readings with a thickness

of material of the order of magnitude of the equilibrium layer at different levels between the disphragm and the chamber.

The setup of Figure 8 (*b*) appears exaggerated if one thinks of the source as being a supervoltage roentgen tube, in which case the intensity of radiation is high and long distances can be used. When the source is a radioactive isotope,* however, the distance at which measurements can be made is quite limited.

There are many other experimental difficulties involved in the measurement of tion) coefficients in the case of monochromatic radiation. The main purpose of such measurements is to appraise the characteristics of the radiation under consideration. When the object in view is to obtain data for protection of personnel, the conditions of measurement should be those appropriate to that problem. Let us study by absorption measurements the characteristics of roentgen rays produced at 2.5 million volts, for which data are available in the literature.[7]

A good experimental setup is shown in

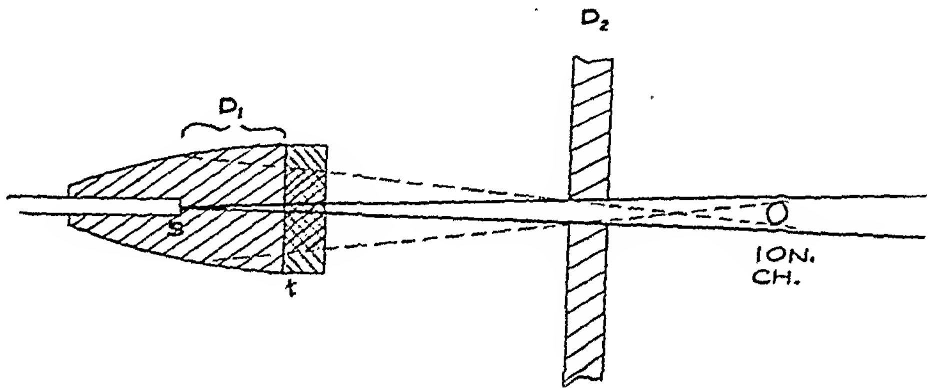


Fig. 9

absorption coefficients in the case of high energy monochromatic radiation. Some of these will become apparent in the discussion of the more practical problem of the measurement of polychromatic radiation.† In physics the study of absorption coefficients of monochromatic radiation has made possible our understanding of the interaction between radiation and matter through the different processes already described. To make use of this background in the simplest fashion we should make measurements of polychromatic radiation under the conditions approximating most closely those required for the proper measurement of absorption (i.e. attenua-

Figure 9. The provisions for preventing scattered radiation from reaching the chamber are obvious. We may point out, however, that the chamber "sees," and therefore may receive, radiation originating in the doubly cross-hatched volume of the absorber. Hence, the necessity for making D_1 of lead thicker than the largest thickness of lead absorber to be used, by several half-value layers. In practice this type of setup is seldom possible. The room in which the roentgen-ray machine is housed is usually small and the lead shield around the target of insufficient thickness. As a result, a considerable amount of direct and scattered radiation is present in every part of the room. A second diaphragm D_2 of sufficient thickness and size can hardly be provided. The usual procedure is then to place the ionization chamber in a lead sleeve or collimator. This is shown in Figure 10. The lead shield around the target is intended for ordinary use of the machine and allows a wide beam of radiation to pass

* *In this case the source is usually very weak and one is forced to use Geiger-Müller counters instead of ionization chambers. The wavelength response of these counters presents a much more difficult problem than that of the ionization function of a chamber, discussed here. The subject is of great practical importance but it would take us too far afield to discuss it in the present paper.*

† *All sources of high energy radiation, with the exception of a few radioactive isotopes, produce polychromatic radiation and there is no practical way of separating it into its monochromatic components.*

through. A large portion of the absorber is strongly irradiated and scattered radiation from all this region can reach the ionization chamber, in spite of the lead sleeve. Scattered radiation from the wall can also reach the chamber, but it can be made negligibly small by using a long sleeve. The chief complication, however, is due to scattered and secondary radiation produced in the sleeve itself. This can be greatly reduced by placing over the incidence end of the collimating diaphragm of small aperture at the incidence end. The curve shows a rapid drop at the beginning followed eventually by a straight line. The curvature indicates that the softest components of the beam were gradually eliminated by increasing thicknesses of lead. On the other hand, the straight line portion of the curve does not prove that the radiation, by this process of differential attenuation, finally became monochromatic and in equilibrium with

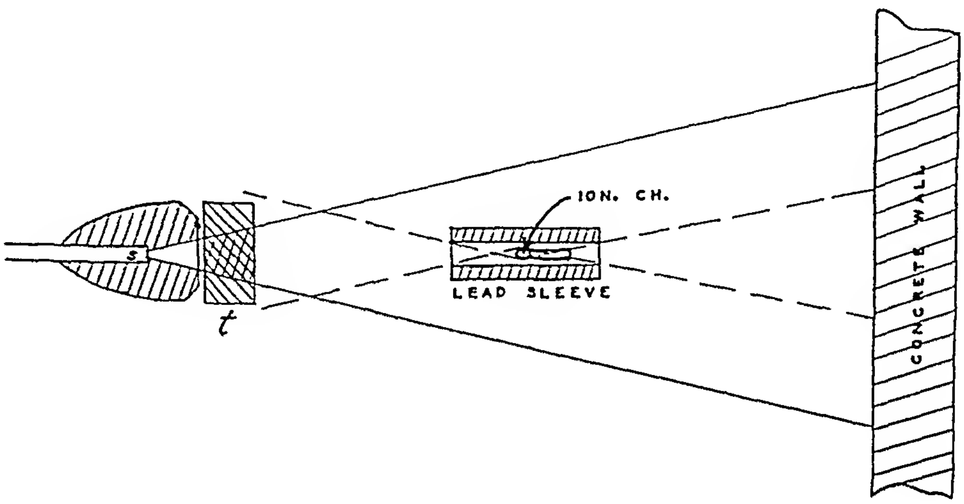


Fig. 10

sleeve a thick lead diaphragm with a small aperture (not shown in Fig. 10). When this second diaphragm is absent, there must be a considerable amount of soft radiation present within the sleeve. The relative amount certainly varies with the wavelength and hence with the thickness of the absorber, at least at first. The significance of the first part of an absorption curve thus obtained is obscured by spurious effects. Fortunately, the interpretation of the first part of the absorption curve of polychromatic radiation is difficult at best and not of great practical importance. Nevertheless, one should strive to avoid complicating factors and thus make results obtained by different investigators more readily comparable.

An absorption curve in lead for a constant voltage of 2,500 kv. is shown in Figure 11, as published by Petrauskas, Van Atta and Myers.[7] It was determined with a "lead sleeve" setup, including, however, a its secondaries, in the range of lead thickness used. That it is not monochromatic radiation of 2,500 kev. may be readily proved by comparing the absorption coefficient derived from the straight portion of the curve with the one for 2,500 kev. (2.5 mev.) given in Figure 5. They are respectively 0.617 and 0.475. Monochromatic radiation with $\mu=0.617$ has an energy of 1,500 kev. and this might be considered to be the monochromatic equivalent of the radiation beam after traversing several centimeters of lead.

The roentgen-ray spectrum produced by a tube voltage of 2,500 kv. contains very little 2,500 kev. radiation. For purposes of illustration let us assume that in the initial spectrum the photons of 1,500 kev. energy are 8 times as numerous as the 2,500 kev. ones. The half-value layers for the two are 1.12 and 1.46 cm. of lead respectively. A lead thickness of 5 cm. corresponds, therefore, to 4.45 hvl for the softer component

and 3.43 hvl for the harder. Since the difference is practically 1 hvl, the harder component gains over the softer one by a factor of 2 in passing through each 5 cm. of lead. Since the softer component was initially 8 times more intense, it is still 4 times more intense than the harder component after the first 5 cm. To be equal in intensity the two must traverse 15 cm. of lead. This example serves to show, also, that in this energy range elimination of the longer wavelength components takes place quite slowly. Nevertheless, it is clear that eventually the shortest wavelength must prevail, even if its intensity is very low initially. In the end, therefore, the radiation should be monochromatic* and of the shortest wavelength present in the beam. This point in an absorption curve is seldom, if ever, reached in practice in the high voltage region. For one thing the intensity gets too low for accurate measurement. The component of highest energy is very weak especially when pulsating voltage is applied to the roentgen tube. The coefficient of absorption is not very sensitive to changes in wavelength.

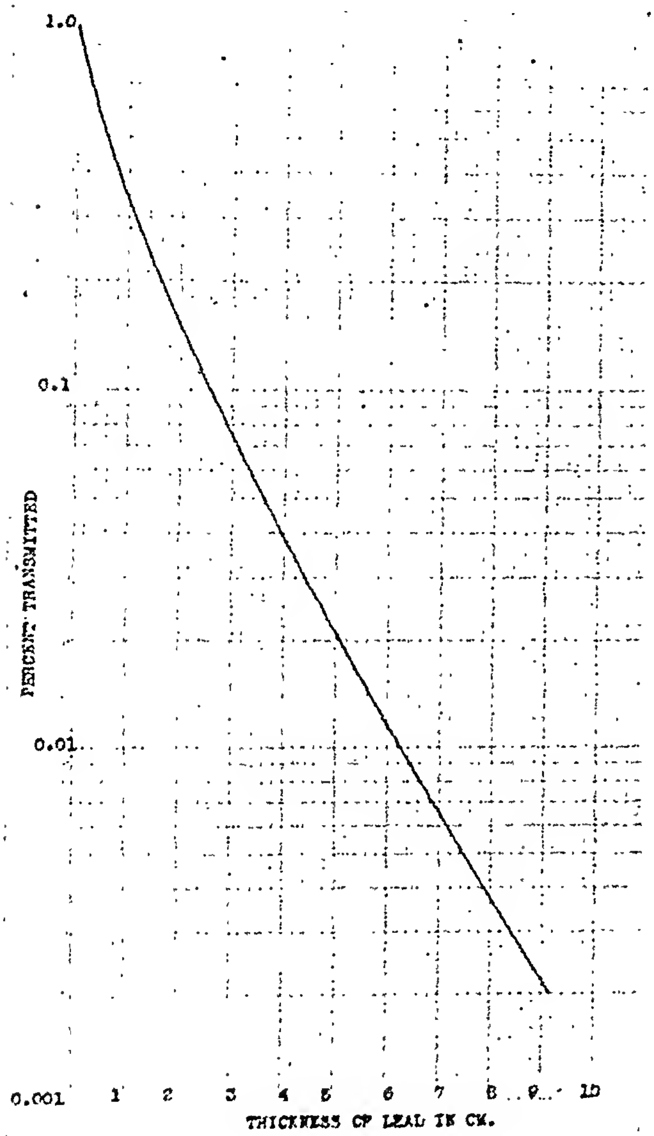


Fig. 11

The efficacy of differential absorption in lead may be judged by inspection of Figure 5. In this connection it is useful to remember that when the coefficients of absorption (or the half-value layers) for two wavelengths differ by 10 per cent, it takes 10 hvl of the absorber for a differential absorption factor of 2.† For a factor of 4 it takes 20 hvl. Few absorption curves determined by actual measurements extend beyond 10 hvl. We may conclude, therefore, that the radiation is far from monochromatic in spite of the straight line absorption curve.

Mention was made earlier that in the supervoltage region the relation between intensity of radiation and ionization chamber readings is not far from linear. Reference to Figure 7 shows, however, that be-

* In equilibrium with its secondaries.

† To obtain a general relation, let

μ_1 = coefficient of absorption of harder component

μ_2 = coefficient of absorption of softer component

(that is, $\mu_2 > \mu_1$)

$$r = \frac{\mu_1}{\mu_2} = \frac{(\mathrm{hvl})_2}{(\mathrm{hvl})_1}$$

f = differential absorption factor, that is, factor by which it is desired that intensity of harder component be higher than that of softer component.

n_1 = number of half-value layers of the harder component required to bring this about, when both components are of equal intensity initially.

Then

$$n_1 = \frac{3.32\, r \log f}{1 - r}$$

or

$$n_1 = \frac{3.32\, \mu_1 \log f}{\mu_2 - \mu_1} = \frac{3.32\, (\mathrm{hvl})_2 \log f}{(\mathrm{hvl})_1 - (\mathrm{hvl})_2}.$$

The equivalent number, n_2, of half-value layers of the softer component is

$$n_2 = n_1 + 3.32 \log f.$$

In the example

$$\frac{\mu_1}{\mu_2} = r = 0.9 \qquad f = 2 \text{ or } 4$$

$$n_1 = \frac{3.32 \times 0.9 \times \log 2}{1 - 0.9} = 9$$

$$n_2 = n_1 + 1 = 10$$

for $f = 4$ $\quad n_1 = 18 \quad n_2 = 20$

tween 1,000 and 2,500 kev. $\tau+\sigma_a$ (for air) varies about 25 per cent. Most of the energy in the 2,500 kv. roentgen-ray beam just considered lies between these limits. As the thickness of lead increases the center of gravity of the energy spectrum shifts It could very readily amount to that if much greater thicknesses of lead had been used. While on the subject, it may be pointed out that this type of effect is very pronounced in the case of roentgen rays produced at voltages up to about 150 kv.

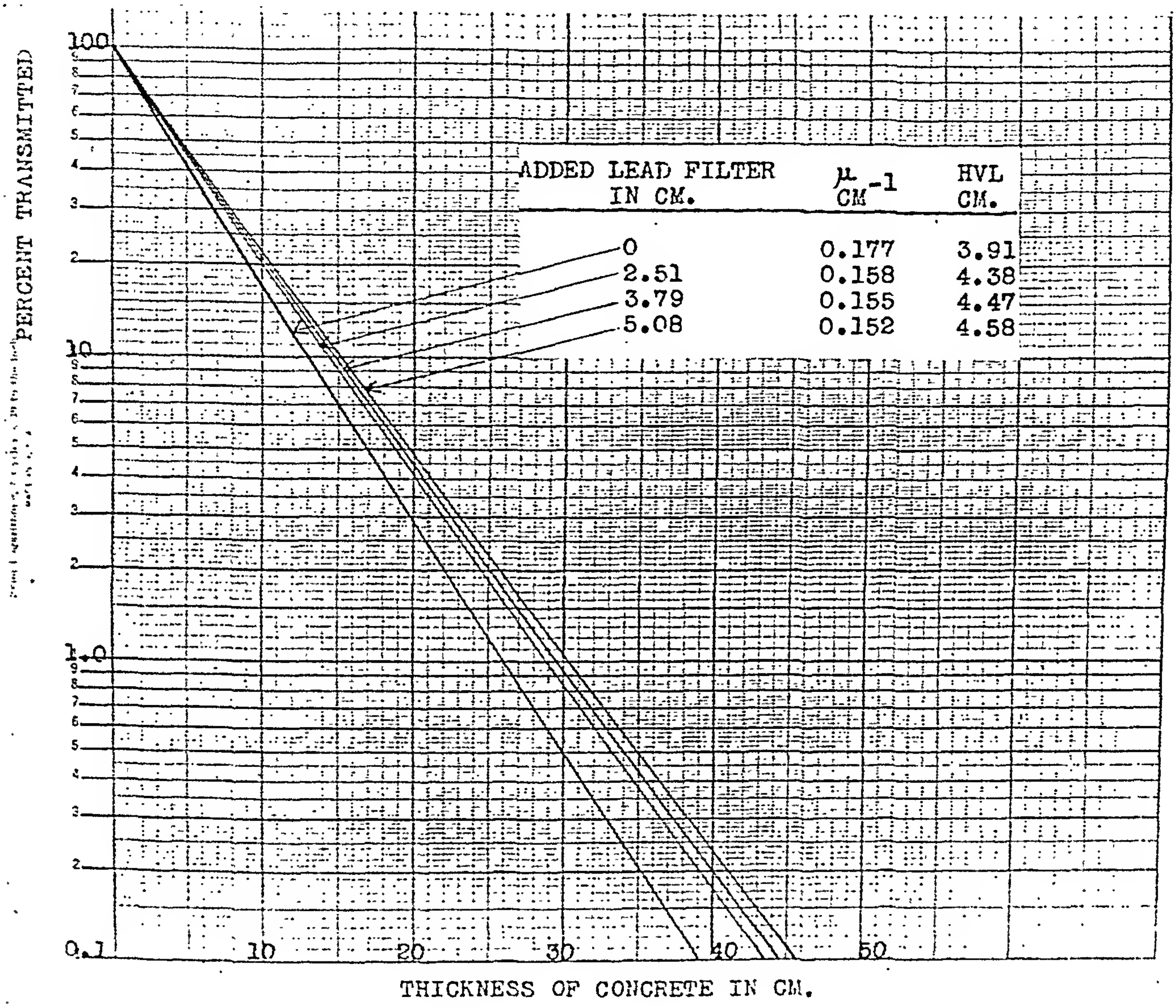


Fig. 12

towards the 2,500 kev. limit. Therefore, the ionization chamber registers a somewhat smaller fraction of the energy reaching it, as the thickness of lead increases. This tends to make the absorption curve, *plotted as ionization current versus thickness*, straighter than it would be if the ionization function of the chamber remained constant. This effect is probably much less than the 25 per cent extreme mentioned above, in the straight part of the curve of Figure 11.

(i.e. less than 100 kev. monochromatic). Inspection of Figure 7 makes this self evident.

The interpretation of absorption curves is important in the problem of protection; we may then dwell on the subject a little longer. The curves of Figure 12 were obtained by Folsom and Focht[3] using very well collimated beams, long distances and "air wall" ionization chambers. For 1,000 kv. roentgen rays the ionization function

of the chamber is very nearly constant and it has no influence on the shape of the curves beyond a few centimeters of concrete. The interesting thing is that these curves are straight but the slope depends on the thickness of the lead filter used. The reason why each curve is straight is, of course, that the coefficient of absorption for concrete does not vary much in the wavelength range involved in each curve. Differential absorption of the longer wavelengths is very ineffective—much less effective than in the case of the lead absorption curve previously discussed—and the radiation is not monochromatic. The lead *filter*, however, does change the quality of the beam (as indicated by the different slopes) and it does so without decreasing the intensity of radiation to the vanishing point. Therefore, with greater thickness of concrete all the curves should tend to assume the same slope. This means that, eventually, at least some of the curves must bend upward. They are straight for reasons already given and because the thickness of concrete used was not sufficiently large. Aside from the fact (pointed out by Folsom and Focht) that narrow beam absorption data are not directly applicable to the protection problem, it should be emphasized that the thickness of absorber used (and the filter) should be as large as is apt to be needed for protection barriers.

We shall analyze now the protection problem with the object of determining, if possible, the conditions under which absorption measurements should be made in the laboratory to be most directly applicable. The problem is simply this: We wish to obtain data which will enable us to design in advance all protective barriers needed in a roentgen-ray installation, with the assurance that protection of personnel will be fully adequate but not extravagant. The economical aspect of the problem, of course, assumes greater importance as the use of higher and higher voltage roentgen-ray generators becomes more common. In the lower voltage range the situation is well in hand for three reasons: (1) lead is largely used as protective material and the scattering problem is not serious; (2) measurements made on existing installations provide a check on calculations and the results of the comparison are available for future use; (3) the cost of protection is not high.* It consists largely of labor costs and the use of a thicker lead barrier "to be on the safe side" entails little additional expense.

If the permissible daily dose for continued exposure of the whole body is 0.1 r, it means that radiation of an average dosage rate of 12.5 mr/hr. is present—or at any rate is allowable—in rooms occupied by personnel. This radiation is subject to the same physical laws as radiation of higher dosage rate. It is, therefore, absorbed, scattered and rescattered in the room. If then, the *total* dosage rate to which an individual is exposed cannot exceed 12.5 mr per hour, the dosage rate of the radiation *entering* the room must be lower. How much lower? Also, and more important, how can we calculate the dosage rate of the radiation entering the room? The answers to these questions (and others) must be known before we can design protective barriers that are not only sufficient but economical.

In Figure 13 the source of high voltage roentgen rays (say, 2,000 kv.) is shown in one room, an ionization chamber in an adjoining room separated from the former by a thick concrete wall. The radial lines indicate the directions from which the chamber receives radiation, no attempt being made to represent the magnitudes of the different components. The heavy lines proceeding from the source to the chamber indicate the "narrow" beam that might be used in the making of measurements of the type previously discussed. If such measurements were actually made in the room shown, it would be found that the unrestricted beam reading would be several times higher than the one obtained

* The cost relative to the price of the machine is, nevertheless, high.

with the collimated narrow beam. The distinction between absorption measurements intended for absorption coefficient determinations and those applicable to protection problems is not, therefore, a mere refinement.

Inasmuch as the laws of interaction of radiation and matter have been worked out quite satisfactorily, in principle one could calculate the dosage rate at different points in the room, having first ascertained the characteristics of the radiation by appropriate narrow beam measurements. The necessary reduction factor in dosage rate that the barrier must bring about is so great, however, that the radiation undergoes many repeated changes in wavelength and direction in its passage through the barrier. Thus the mathematical problem becomes too involved and simplifying assumptions are introduced to bring it into manageable form. This reduces the reliability of the results to an extent that is difficult to estimate.

A second method by which the necessary data may be obtained is by interpolation and extrapolation making use of existing installations. Thus one could calculate the dosage rate on the basis of absorption coefficients, then make actual measurements at the point in question and determine the correction factor to apply to the calculated value. By doing this under many different conditions, certain empirical relations could be obtained which could be applied to the design of new installations. In making use of this method care should be exercised not to extrapolate too far. That is, the conditions of the new installation should not be too far removed from those on which the empirical relations are based. While this scheme is feasible, it is actually a matter of considerable difficulty to obtain the necessary experimental information. Aside from geographical limitations, existing supervoltage installations are so constructed that seldom can one obtain the desired data without objectionable complicating factors. Nevertheless more work of this sort should be done. After all, it is only by making careful measurements after the installation has been completed that the accuracy of the calculations can be checked.

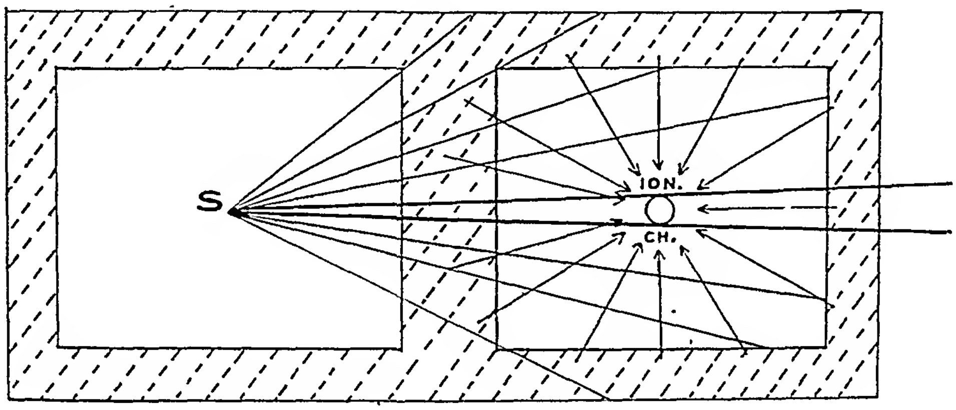


Fig. 13

One difficulty with the "correction factor" method just discussed deserves mention. The simplest way in which to apply this method would be to use the absorption curve for the radiation and material under consideration, and to determine therefrom the minimum thickness of the barrier. Then the thickness would be increased by an amount determined by the appropriate empirical correction factor. This procedure relies heavily on the absorption curve, which, as we have seen, is influenced by the experimental setup. For one thing the cross-section of the beam used is very important.* What constitutes a "narrow" beam has been largely a matter of personal

* See, for instance, Folsom and Focht's paper already referred to.

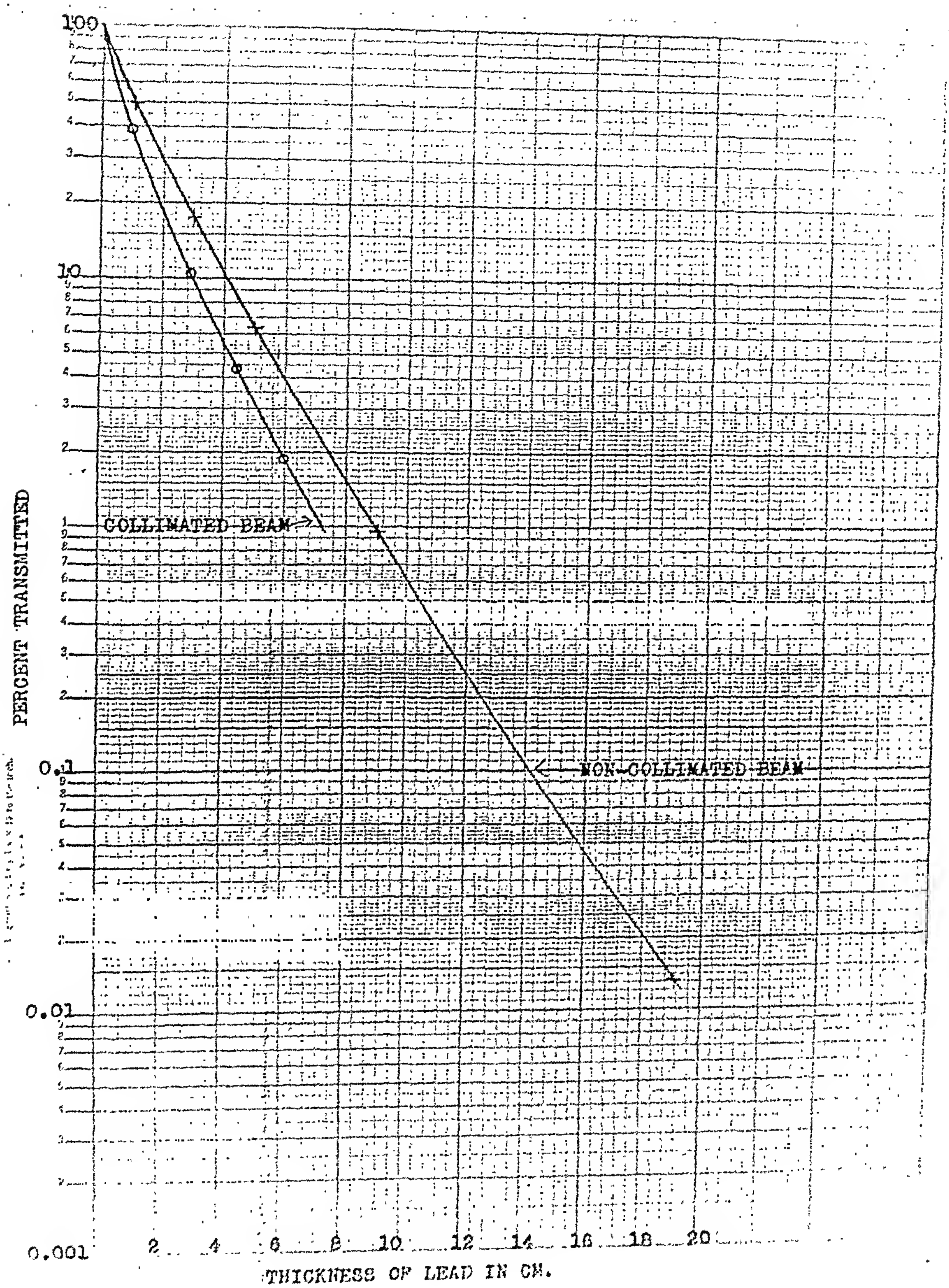


Fig. 14

opinion in the past. Very narrow beams are difficult to use and one tends to compromise. Therefore, the calculated minimum thickness referred to above is subject to considerable variations, depending on the choice of experimental setup, and in particular on the size of beam and on the initial filter used. It should be remembered

that a certain percentage difference in the coefficients of absorption (slopes of the curves) makes the same percentage difference in the *total* thickness of the barrier. On the other hand, a small percentage difference in the absorption coefficients makes a large difference in the dosage rates of the radiation transmitted through a thick barrier. For example, a 15 hvl concrete barrier would be either ($15\times 3.91=$) 58.7 or ($15\times 4.58=$) 68.7 cm. thick depending on which one of the two extreme curves in Figure 12 is chosen. If the steeper curve is chosen ($\mu=0.177$) but the radiation actually behaves as if the coefficient of absorption were 0.152 (17 per cent difference in μ), the dosage rate of the radiation transmitted through 58.7 cm. of concrete would be 4.27 times higher.*

In view of the numerous difficulties encountered in the determination of narrow beam absorption curves in the supervoltage region, it is desirable to find a more practical scheme. It is clear that some sort of absorption curve is necessary. Preferably we should have one that is not so sensitive to differences in experimental setup. If we place the absorbing material completely around the ionization chamber, we avoid many difficulties. We also obtain an absorption curve that represents the conditions of the protection problem more closely than the narrow beam curve determined in the customary way. The ionization chamber might be said to represent a miniature room surrounded by walls of the protective material. There are at present no absorption curves obtained in this way and comparison with conventional absorption curves is impossible. It is not difficult to predict, however, that the slope of such a curve would be less than that of its narrow beam counterpart. Using this more representative type of absorption curve to determine the thickness of the desired barrier, we are bound to get a closer approximation to the correct thickness. The correction factors, which in any event must be determined empirically, will then be much smaller.

We may examine for a moment an absorption curve obtained by a method that in some respects resembles the one suggested above. The curve was obtained by Braestrup† by *surrounding the source* (radium) with lead cylinders of increasing thickness. For comparison Figure 14 contains, also, an absorption curve obtained with a well collimated gamma-ray beam. The same spherical ionization chambers were used in both cases and they were never closer to the radium than 1 meter. The difference between the two curves is not due to radiation scattered by the walls of the room and objects in it. It is almost entirely due to radiation scattered by the mass of lead around the source. When the absorber is placed around the chamber a similar situation exists in that much of the radiation scattered in the material reaches the chamber. In the case of the gamma rays of radium it is interesting to note that it makes little difference whether the lead is placed around the source *or* around the chamber, at least up to a thickness of 4 cm. as may be seen from Table I.‡

Table I

Thickness of Lead Shield cm.	Relative Ionization with	
	Lead shield around radium	Lead shield around chamber
0	100.0	100.0
0.32	75.0	82.5
2.0	32.1	34.0
4.0	11.6	12.4

Roentgen radiation in the energy range

* This figure may be obtained readily in two ways: The correct thickness for $\mu=0.152$ is 68.7 cm. Therefore, the barrier is thinner than it should be by 10 cm., which is equivalent to $\frac{10}{4.58}=2.18$ hvl. Hence by reference to scales $A-B$ of Figure 11 the dosage rate is 4.27 times higher. Or use may be made of the relation given in the footnote on p. 572, in which case $r=0.86$, $n=12.8$ $\left(\text{that is, } \frac{58.7}{4.58}\right)$ and solving the equation $f=4.27$.

† Personal communication.

‡ I am indebted to Dr. E. H. Quimby for these measurements.

in which pair formation is important is produced at present by generators of the "betatron" type,[5,8] operating at maximum electron energies of a few million to 100 million electron volts. When electrons with this energy impinge on a target, they produce polychromatic roentgen rays. Just as at lower voltages the energy of the most energetic photons is equal to that of the impinging electrons and the bulk of the radiation is of much lower energy—about one-half or two-thirds of the maximum. It is desirable, therefore, to obtain absorption curves for the purpose of studying the interaction of radiation and matter in this new range, and for protection purposes. As already explained, the experimental conditions must be adjusted to the purpose.

In the range of 20 to 100 million volt roentgen rays the protection problem is greatly simplified by the fact that most of the radiation is emitted within a very narrow cone with its axis in the direction of travel of the electrons at the time of impact. For 20 and 100 million volt roentgen rays the vertex angle of this cone is approximately 9 and 2 degrees, respectively. Radiation emitted at 90° to this axis is not only much less intense but also much softer. Accordingly, if the beam of radiation is fixed in position or is adjustable to a limited degree, *thick* protective barriers are needed only in certain directions. There is, also, a second favorable element in that substances of high atomic number become increasingly more effective as absorbers as the voltage increases beyond the point at which pair formation sets in. As previously mentioned lead is most transparent to 3 to 4 mev. roentgen rays. It attenuates 20 mev. roentgen rays at the same rate that it attenuates 1 mev. roentgen rays (see Fig. 5). With 100 mv. roentgen rays lead behaves as a filter but in the opposite direction to that with which we are familiar in the low voltage range. It tends to *increase* the average wavelength of the transmitted radiation up to that corresponding to 3 or 4 mev. In the case of concrete, which is commonly used in the supervoltage range, the situation is less favorable because pair formation in this material is less and does not become very prominent until photon energies of the order of 10 mev. are reached. Also, the coefficient of absorption of concrete increases very slowly beyond 10 mev. This applies to all substances of low or medium atomic number, and therefore concrete and lead are still the most practical materials to use for protective barriers in the energy range above 10 mev.*

The measurement of multimillion† volt roentgen rays for protection purposes involves the fundamental question of the biological effectiveness of such roentgen rays. While little is known from actual experience, it may be assumed with confidence that a certain amount of (ionization) energy actually absorbed by a living cell will produce the same biological changes, whether the energy is imparted to the cell by supervoltage or multimillion volt roentgen rays—provided all other conditions are the same. The latter statement is not intended as a "tricky" reservation. Thus, obviously, the distribution of absorbed energy throughout the biological object and the time factors must be the same in order to make any valid comparison at all.

The distribution of the ionization produced in the human body will be quite different in the case of multimillion volt roentgen rays for three reasons: (1) the radiation is more penetrating; (2) more

* *High energy photons cause nuclear reactions resulting in the production of radioactive isotopes, which emit ionizing radiations. The choice of material for a protective barrier may be influenced to some extent by this consideration. The radioactive isotopes produced in the barrier (or other object in the path of the roentgen rays) would emit radiation continuously even when the generator is shut down. Fortunately, the efficiency of production of radioactive isotopes is very low and in general this is not a serious complication in the energy range attained thus far (20 to 100 mv.).*

† *This term is not very good but it fills the need for a single expression to use in referring to roentgen rays produced at voltages of several million volts and over. The term "supervoltage," which has found wide acceptance might well be limited to the range of 1 or 2 million volts. A distinction should be made between the energy range in which the Compton process of absorption predominates and the one in which pair formation becomes important.*

important than this, when the beam initially is devoid of "secondaries" the depth dose is actually much higher than the skin dose, at depths of the order of several centimeters;[5] (3) since the probability of pair formation increases with the square of the atomic number,[4] tissues such as bone, containing fairly high atomic number elements, will absorb more energy than other tissues in a radiation field of equal intensity. If the tissue dose is measured properly,[1] in the region or regions in which the biological effect originates and develops, these physical differences can be taken into account, and the biological changes to be expected may be predicted. We shall discuss this matter only briefly and so far as it concerns the present problem.

In making protection measurements one must take into account the unusual distribution of absorbed energy in the human body just mentioned. At what depth in the soft tissues of the body the maximum energy absorption occurs depends on the photon energy of the radiation and on its "equilibrium status."* The importance of the latter was demonstrated first in the case of the gamma rays of radium,[2] in which energy range it begins to be appreciable. In the case of multimillion volt roentgen rays it is incomparably more marked. The layer of tissue through which the radiation must pass to be in equilibrium with the secondary electrons is approximately 3.5 cm. in the case of 20 mv. roentgen rays[5] and may reach 9 or 10 cm.† at 100 mv. The difference between the dose at the surface of the skin and that at the depth at which it is highest, may be very large, depending on how completely "stripped" of secondary electrons the roentgen-ray beam is when it reaches the skin. It is obvious that for protection purposes we are interested in this maximum depth dose. To get a reasonably close approximation of its value the ionization chamber must be surrounded by a thickness of tissue equivalent material equal to the equilibrium thickness. This varies with the energy of the radiation and must be determined experimentally. It also varies with the equilibrium status of the radiation. Because of the large thickness needed at very high voltages (say 100 mv.) the absorption of radiation in this layer is considerable. Hence, if the radiation is already in equilibrium with its secondaries, an ionization chamber surrounded by the equilibrium layer will read lower than it should to represent the radiation that (some internal organs of) the human body would receive. It is best to determine the equilibrium status of the radiation at the time and place of measurement by gradually increasing the thickness of material surrounding the chamber. (A sharp maximum in the ionization reading should not be expected.)

It might be mentioned in this connection that the equilibrium status depends on the nature of the material traversed by the radiation. One hundred million volt roentgen rays passing through a very large thickness of lead would be in equilibrium with the secondaries so far as lead is concerned, but not with respect to the tissue equivalent material surrounding the ionization chamber. This is because the pair formation process depends on the square of the atomic number. The same thing applies to concrete but to a much smaller extent. A narrow beam of 100 mv. roentgen rays passing through a thick concrete wall is not in equilibrium with its secondaries at a considerable distance beyond the wall, for another reason: the secondaries tend to be scattered out of the narrow beam.

* By "equilibrium status" is meant the extent to which "secondaries" are present. "Secondaries" is a loose term referring to electrons, positrons, scattered radiation, annihilation radiation, etc. The thickness of matter through which the radiation must pass to be in equilibrium with its secondaries depends, among other things, on what secondaries we are interested in. If we consider only electrons, the equilibrium thickness is much less than when secondary photons are included. The thickness also depends on the geometry of the beam and absorber (parallel or divergent rays, extent of absorbing mass, etc.).

† This thickness is governed largely by the maximum range of the secondary electrons produced in the absorber, and to some extent by the experimental conditions. At very high energies electrons lose much energy in "lumps" by radiative processes and the range is shorter than it would be otherwise.

to photons when the positron is annihilated. While it should be registered in the measurement, this energy is not immediately available to produce ions. This effect is appreciable in the relatively low energy range of several mev. because 1,022 kev. is then a substantial fraction of the total energy imparted to the pair. The difficulty will have to be resolved by agreement at some future International Congress of Radiology.

Referring back to Figure 7 it may be pointed out that if the conditions of measurement meet the requirements of the present definition of the roentgen, the ionization current readings will be very nearly proportional to the roentgen-ray energy flux in the region of 8 to 300 mev. The dotted portion of the curve in Figure 7 represents the sum of σ_a and σ_p, which is 2×10^{-5} cm.$^{-1}$ at 8 or 9 mev. and remains nearly at this value up to about 300 mev.

Before closing, it is desirable to point out that the mathematical part of protection problems in the multimillion volt range may be solved by the same methods developed in Part 2 of this paper.* However, it should be remembered that equation (1) is based on a permissible daily dose of 0.1 r. This is higher by a factor of 2 or more than the value applicable to the very high energy range. The charts derived from equation (1) may be used, but one or more half-value layers must be added to the number determined thereby, depending on the appropriate value of the permissible daily dose.

SUMMARY

Solution of Protection Problems in Terms of the Half-Value Layer. The accepted permissible daily dose of roentgen rays for long continued exposure of the whole body is 0.1 r. For an eight hour working day this corresponds to a dosage rate of 12.5 milliroentgens per hour (12.5 mr/hr.). Given a roentgen-ray machine with a certain output and quality of radiation, the protection problem consists of determining the thicknesses of absorbing barriers to be placed around the source in order to reduce the dosage rate to 12.5 mr/hr. in all regularly occupied regions.

If the dosage rate at a given point is 1 r/min., it may be reduced to ½ r/min. by interposing a protective barrier of any material of thickness equal to one half-value layer (1 hvl). Addition of another half-value layer reduces the dosage rate to ¼ r/min., and so on. In this way it is found that to reduce the dosage rate to 12.5 mr/hr. a barrier of 12.2 half-value layers be interposed between the source and the point in question. If the initial dosage rate is 2 r/min. instead of 1 r/min. one additional half-value layer is required; if 4 r/min. 2 additional half-value layers are needed, and so on. On the other hand, at a point twice as far from the source, the initial dosage rate will be ¼ r/min. instead of 1 r/min. and the thickness of the barrier may be decreased by 2 half-value layers. If the distance is doubled again 2 more half-value layers may be subtracted, and so forth. It follows, therefore, that both the radiation output and distance factors of a problem may be expressed in terms of the corresponding number of half-value layers to be added or subtracted. The problem is then reduced to one of algebraic addition instead of multiplication and division. This makes possible the construction of simple graphical charts for the solution of practical problems. Figure 2 in the text is the most useful one.†

Having determined (by means of Fig. 2) the number of half-value layers required in the barrier to reduce the dosage rate at a given point to 12.5 mr/hr., it is necessary to translate it into actual thickness of the material to be used. This requires an absorption curve for the radiation and the material under consideration. If the curve, plotted to a semilogarithmic scale, is a straight line, the half-value layer is constant throughout the thickness range and its value may be derived readily from the curve. The thickness of the barrier is

* While the emitted radiation is confined largely within a narrow cone, the inverse square law still holds.

† Large blueprints of this chart may be obtained from the author at cost.

obtained by multiplying the number of half-value layers required by the thickness of the half-value layer. If the absorption curve is not straight a different procedure (explained in the text) must be followed. It should be noted that the fundamental data embodied in the absorption curve are necessary for the solution of protection problems, no matter what method is used.

Discussion of Absorption Curves. Physicists are interested primarily in the laws that govern the interaction of radiation and matter. To study the different processes of interaction, absorption curves are determined under appropriate conditions. In general, these conditions do not fulfill the special requirements of the protection problem and such curves should not be used for this purpose. The discrepancy becomes more marked at the higher voltages (1 million and over) which are coming into prominent use in medicine and industry. In this voltage range the factor of uncertainty at present is too large to permit the design of barriers that provide adequate protection *at minimum cost.*

Practical limitations make it very difficult to duplicate in the laboratory the numerous and varied conditions obtaining in high voltage installations. Nor would it be desirable to do so. It is preferable to obtain basic experimental data that can be applied most directly to protection problems in general, taking care of special conditions by suitable allowances. The basic data should be such that these allowances will be small and will introduce little uncertainty in the final result. It is suggested that absorption curves determined by placing the absorber completely around a properly designed "air-wall" ionization chamber, would serve this purpose best. Such curves are not apt to be influenced markedly by the experimental setup and can be determined readily in any laboratory.

Some Protection Problems Peculiar to Multimillion Volt Roentgen Rays. The expression "multimillion volt roentgen rays" is suggested—with some reluctance—to denote the energy range in which absorption by the pair formation process plays an important part. Depending on the material under consideration, this range extends from a few million volts up.

In this case the protection problem is simplified by the fact that the emitted roentgen rays are confined largely within a narrow cone and that all processes of interaction *tend* to maintain the energy in the "forward direction."

In this energy range, lead becomes again a very efficient absorber. Concrete is relatively less efficient than lead but more practical for large barriers.

The measurement of these roentgen rays and the determination of absorption curves present special problems which have not been solved. The conditions under which measurements are to be made to conform with the requirements of the present definition of the roentgen should be agreed upon.

With multimillion volt roentgen rays the distribution of radiation in the human body is quite different from that produced by ordinary roentgen rays. The "depth" dose for a single beam may be many times higher than the skin dose. The ionization produced in a tissue (or energy absorbed) depends also on the presence of elements of high atomic number not only in the tissue and at the point in question but in tissues at a considerable distance. This is because the pair formation process depends on the square of the atomic number and the ranges of the resulting electron and positron may be a few centimeters.

Because of the relatively larger amount of radiation reaching the blood forming organs and the excess of ionizing particles reaching the bone marrow from the higher differential pair formation in bone, the permissible daily dose for exposure of the whole body to multimillion volt roentgen rays should be considerably lower than 0.1 roentgen.

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REFERENCES

1. Failla, G. Measurement of tissue dose in terms of the same unit for all ionizing radiations. *Radiology*, 1937, *29*, 202–215.
2. Failla, G., Twombly, G., and Marinelli, L. D. Method for decreasing the ionization in the skin applicable to supervoltage x-ray therapy. *Radiology*, 1937, *28*, 693–703.
3. Folsom, T. R., and Focht, E. F. Data on the attenuation of narrow and broad beams of 1,000 kilovolt (peak) roentgen rays by lead, concrete and water. Am. J. Roentgenol. & Rad. Therapy, 1944, *51*, 76–82.
4. Heitler, W. The Quantum Theory of Radiation. Oxford University Press, New York, 1944. (General reference.)
5. Kerst, D. W. The betatron. *Radiology*, 1943, *40*, 115–119.
6. Koch, H. W., Kerst, D. W., and Morrison, P. Experimental depth dose for 5, 10, 15 and 20-million-volt x-rays. *Radiology*, 1943, *40*, 120–127.
7. Petrauskas, A. A., Van Atta, L. C., and Myers, F. E. Measurements on x-ray production and absorption in the range 0.7 to 2.5 mv. *Phys. Rev.*, 1943, *63*, 389–399.
8. Westendorp, W. F., and Charlton, E. E. A 100-million volt induction electron accelerator. *J. Applied Physics*, Oct., 1945, *16*, 581–593.

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EXPERIENCES WITH THE ROENTGEN-RAY TUBE

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THE fifty year period commemorated by this number of The American Journal of Roentgenology and Radium Therapy began during my senior year as an electrical engineering student at the Massachusetts Institute of Technology. The announcement of Röntgen's great discovery was soon followed by intensive work by several members of the teaching staff at the Massachusetts Institute of Technology on various forms of high tension generators to operate the tube. This work was done in collaboration with Dr. Francis H. Williams of Boston, one of the earliest of the pioneers in the application of roentgen rays in the medical field, and it was my exciting privilege to witness many of these developments.

In addition to this, I spent many evenings with a friend who had a large static machine from which various roentgen-ray tubes were operated, and later built a static machine of my own for the same purpose.

I became acquainted very early with the destructive effect of roentgen rays upon living tissue. In fact, it was only a few months after the announcement of Röntgen's discovery that I required medical care for a roentgen burn covering most of the back of one hand.

Meeting with Röntgen

In 1898, while a student in the University of Leipzig, I was greatly thrilled one day when Professor Röntgen entered the room in which I was working on my thesis. The Herr Geheimrath Gustav Weidemann had recently died and Röntgen had been called to take his place as head of the physics department. The impression which I received was an unforgettable one, the more so as I had previously pictured Röntgen as a frail and sickly looking individual rather than the robust specimen I then saw before me who was so tall that he could just enter the door without stooping.

The new Physics Institute in Leipzig had just been completed and the living quarters of the Röntgens would have been on the top floor; but the front windows overlooked the cemetery, and I heard that this view proved unacceptable to Mrs. Röntgen. Be that as it may, the call to Leipzig was not accepted.

Roentgen Tube as Vacuum Furnace

In 1905, when I left the Massachusetts Institute of Technology and joined the staff of the Research Laboratory in Schenectady, I found there an urgent need for a vacuum furnace for melting refractory metals, including tungsten, which were being studied in the hope of finding something better than carbon for the filament of the incandescent lamp. My early experience with roentgen-ray tubes naturally suggested that any material placed at the focus of the cathode rays in such a tube could be either melted or vaporized and, because of the vacuum, without contamination from the atmosphere. So I returned to the Massachusetts Institute of Technology and for several weeks, with the help of a large Heinz induction coil and other equipment kindly lent me by the physics department, I had the experience of working on the development of roentgen tubes in which, for the first time perhaps, one wanted the targets to melt. For these experiments I did not get beyond the stage of using graphite targets. This was perhaps fortunate for me, as graphite, with its low atomic number, is a very inefficient source of roentgen rays, and I was using much energy in the tubes and did not have adequate means of protection. In fact, when Dr. Francis Williams visited me to acquaint himself with the roentgen-ray output of one of the tubes, he said, upon

leaving, that in all his experience he had never before been so much exposed to the rays.

Tungsten Target Development

In Schenectady, when, after several years' work on tungsten, we had succeeded in making that originally brittle metal ductile and had learned how to make good lamp filaments from it, we looked for other applications.

One of the first of these was as a substitute for platinum in the target of the roentgen tube.

Experiments were needed not only to determine design features but also to learn the best metallurgical characteristics of the tungsten metal for the target face. To facilitate the experiments the most powerful roentgen generator of that time, a 10 kw. Snook transformer machine, was acquired. As the purpose of the study was the development of as robust a target as possible, the experiments involved serious overloading of the tubes. This overloading developed weaknesses in this type of tube, which manifested themselves in the form of punctures in the glass envelopes and in cracks due to local overheating. These troubles were subsequently reduced by operating the tubes immersed in oil, but new limitations then presented themselves. With the heavier loads which could be used with oil immersion the aluminum cathodes melted. Then there was the ever-present difficulty of controlling the gas pressure in the tubes.

Experiments Leading to the Development of the Hot Cathode High Vacuum Tube

To avoid the melting of the aluminum cathodes, we tried replacing them with tungsten. This resulted in a tube which was hopelessly unstable ("cranky" in the language of the time).

In another tube, the target and cathode were both made of massive tungsten and identical in form. This tube also was very unstable. The cathode showed essentially the same heating as the target, and the positive ions which bombarded it were about as sharply focused as were the electrons striking the target. It was at first impossible to operate it for more than an instant at a time as, with the application of high voltage, the gas would immediately clean up. It later developed, however, that if the gas pressure were then quickly increased by means of the regulator, the tube could again be operated for an instant, and that if this procedure were repeated several times in quick succession the cathode would become very hot and, in this condition, the tube could be operated continuously. This seemed to bespeak interesting possibilities for a tube in which the cathode could readily be heated at will. The idea of getting electrons from a hot body was not new. Edison had observed it in the incandescent lamp, and O. W. Richardson had investigated the relation between electron emission and temperature. There was, however, much skepticism among physicists at the time as to whether electron emission would continue in case the gas were completely removed from the hot body.

At just the time, however, when we had become conscious of the fact that most of the limitations of the original type of roentgen tube were due to the gas content, without which it could not operate, and were wishing for a stable source of electrons in a high vacuum, Dr. Irving Langmuir in our laboratory was studying electron emission from hot tungsten filaments and finding that even in the highest vacuum the emission was stable and reproducible and that it was even favored in amount by freeing the cathode filament of its original gas content.

These circumstances led me to the construction of experimental high vacuum tubes with a heated tungsten filament as cathode and a tungsten disc as anode. Until these tubes had been continuously pumped for many hours by an exhaust system which was good at the time, but which would now be considered very slow, they showed some of the green fluorescence

of the glass which had always attended the operation of a roentgen tube; but as the electrodes became freed of gas this fluorescence became less and finally disappeared completely. The tube was then stable and controllable, and we were able to satisfy ourselves that its behavior was the same as it would be even if it had a perfect vacuum. The positive ions, essential to the operation of the earlier tubes, were no longer needed and the limitations, most of which were due to the presence of those positive ions, were gone with them.

First Public Demonstration of the New Tube

Dr. Lewis Gregory Cole in New York was the first roentgenologist to have his office equipped with the new type of tube. To introduce it and me to the medical profession, he gave a dinner in New York on December 27, 1913, to which he had invited many prominent roentgenologists. A powerful high voltage generator had been installed in the dining room by Dr. Harry Waite, of the firm of Waite and Bartlett, and with it I was privileged to demonstrate the new tube. On thinking of it now, it seems surprising that the audience stayed through the demonstration. Up to that time the capacity of high voltage roentgen-ray generators had been considerably in excess of what the tubes could stand for any length of time, but with one of the new tubes having a sufficiently large focal spot this was no longer true. I opened the machine up wide and, with the limited amount of protection which the open lead-glass bowl of that time afforded, the audience must have received much more roentgen radiation than they were accustomed to.

Assistance from the Medical Profession

Drs. Lewis Gregory Cole, James T. Case, Walter Dodd, Eugene Caldwell, George E. Pfahler, Preston M. Hickey, and many other roentgenologists, were very helpful to us in those early days in adapting the new tube to the various medical applications.

Mystery Connected with Roentgenography

The gas-filled roentgen tube had not been easy to control and its successful use had called for both patience and experience. It was probably due to the idiosyncrasies of that type of tube that it was not uncommon to hear an expert roentgenologist say that once upon a time he had made a wonderful roentgenogram whose quality he had never since been able to equal. There seemed to be some mystery connected with this—possibly some particular roentgen-ray spectrum was most desirable.

A factor which had contributed to the difficulty of clearing up the mystery was the run-away tendency of the discharge through the gas-filled tube. This had made it necessary that the high voltage source employed should not have good regulation—that is, that for any given setting of the controls, its voltage should fall rapidly with the milliamperage drawn by the tube.

As a result, it had always been very difficult to know what voltage had been effective in producing a given roentgenogram. As ordinarily used, the parallel spark-gap indicated the voltage required to initiate the discharge, but this was usually quite different from, and appreciably higher than, the voltage across the tube when it was later carrying current and so producing roentgen rays.

With the new stable tube, in which the starting and running voltages were the same, we found it desirable to use a high voltage source which did not have a falling voltage characteristic, but instead had good regulation. It was then possible to know in advance what both the milliamperage and the voltage were going to be.

Another factor which must have played some rôle in creating the mystery was the size of focal spot. In a gas tube this was not constant but could vary appreciably with the pressure even during an exposure. Not only this, but as the pressure changed, the position of the focal spot could change also.

There was at the time but little knowledge concerning the matter of focal spot

size. It was quite common for the manufacturer to receive an order for a tube with "pin-point focus." Such a tube, had it been delivered, would of course have been unsatisfactory because of the energy limitation which this would have imposed. This limited knowledge concerning the size of focal spot was such a handicap in the art that for some time after beginning the sale of the hot cathode tube, for educational purposes we supplied with each one a natural size roentgen-ray pinhole camera picture of its focal spot.

Solution of the Mystery

With the hot-cathode tube, in which current and voltage were under independent and accurate control, and the focal spot was of known and unvarying size and fixed location, we were in a position to attempt the solution of the mystery concerning that occasional outstanding roentgenogram that could not be duplicated. As a subject was needed, I called on one of my medical friends for assistance. (I had temporarily and unintentionally sacrificed my own back hair to previous experiments and did not like to practice on other living subjects.) My friend provided me with material which was very useful over a period of months. I wish that I might make fitting acknowledgment at this time to the willing and complacent subject of those experiments. (I can't think of it even today without smelling formalin.)

Later experiments with the detached leg of another passive subject led to a serious misunderstanding. For, upon the completion of these experiments, we wrapped the member in question in a fabric which was easily available to us, varnished cambric, and took it to the works' incinerator. The operator in charge removed the cover and we inserted the package, making no attempt at explanation, as the attendant did not understand much English. It seems that after we left, he raised the cover of the incinerator, and, looking into the fiery furnace, saw our varnished cambric unwrap itself, revealing the seeming evidence of a ghastly crime. We later received a visit from our works' detective, who was in a very serious mood. We explained and explained, but have never been sure that he has ceased to regard us with suspicion.

The conclusion drawn from these experiments was that there was no mystery—that, other things being equal, contrast was determined solely by the voltage used and that definition was a function of the size and fixity of position of the focal spot. We concluded that if one had his choice he would not use the mixture of rays which the tube gives, but would take monochromatic radiation of a wavelength dependent on the thickness of the part to be roentgenographed; but that, not having this choice, he must be content with that mixture of rays coming from the tube when operated with the voltage which gives the desired contrast. Increasing the breadth of the spectrum used, by making a part of the exposure with low voltage and the rest with high, did not help.

Field Currents

It appeared early in the course of our work that if cathode and target were brought very close together, or if there were a sharp point on the cathode, a high voltage discharge could take place even from a cold cathode and in the highest attainable vacuum.

In poorer vacua a similar effect had been observed and described by H. A. Rowland, N. R. Carmichael and L. J. Briggs and by R. W. Wood.

Upon learning that electrons could be pulled out of a cold cathode even in the highest vacuum by means of a high potential gradient, the question arose as to whether a tube based upon this principle might not, because of the greater simplicity involved in the control equipment, be more attractive than a hot cathode tube.

Extensive efforts which we made at the time, however, as well as all subsequent experience, have borne out the conclusion then reached that such a discharge is not

sufficiently stable. Nor does it offer the great flexibility of the hot cathode tube permitting independent control of milliamperage and kilovoltage.

Multisection Tubes

Not only did we decide not to make use of field currents but it soon developed that we must take steps to avoid them, as they otherwise set a limit to the voltage which a tube could support. For operation at high voltage we found it helpful to avoid sharp edges and corners on the electrodes and to space them well apart. Even with these and other precautions, however, it proved difficult to get above a few hundred thousand volts until we hit upon the expedient of grading the potential by means of auxiliary electrodes. The resulting cascade tube made it possible to avoid field current limitations, and so to build tubes for any desired voltage.

Radiator Tube Developed for World War I

World War I brought interesting experiences in connection with the development of roentgen-ray equipment. For use near the front it was clearly desirable to have a simple self-contained and dependable generating outfit of adequate power and maximum portability. It was obviously desirable to eliminate if possible the mechanical high voltage rectifying switch which was in general use at the time. This was before the days of the kenotron but was still possible if we could develop a hot cathode roentgen tube which could be depended upon to rectify its own current. To meet this requirement it was imperative that no part of the focal spot should ever reach the temperature at which appreciable thermionic emission would take place, as this would lead to electron bombardment of the cathode filament raising its temperature and causing run-away with consequent destruction of the tube. One factor was very favorable—the amount of available energy was going to be definitely limited by the capacity of the gasoline-electric generator. The "Universal" tube with its solid tungsten target would have been safe for occasional use, starting with a cold target, but not for the very frequent use which the war service required. These considerations led to the development of the "Radiator" tube with its composite target, heavy copper stem and external radiator for rapid heat removal. The target itself was that which had been developed earlier for the gas tube, but much experimentation was required before we were able to free the large mass of copper sufficiently from gas. For roentgen-ray protection, a heavy two-piece lead-glass shield was developed to completely surround the tube. This tube and shield served for both the United States Army Portable and Bedside outfits.

Power Plant for United States Army Portable Outfit

I knew of no light weight gasoline-electric set suitable for the power supply of the Portable outfit. It seemed possible that a motorcycle could to advantage be used as a highly portable power supply and belted to an electric generator at the point where roentgen rays were required. Through the courtesy of the Indian Motorcycle Company, I was provided with a motorcycle and on it I took my first motorcycle ride. One experience was enough to satisfy me that this was not the way to treat the roentgenologist.

Through the application of tungsten contacts in the automobile ignition system, I had become acquainted with Charles F. Kettering, then of the Delco Company, and this connection suggested the one-kilowatt house lighting set of that company. This was a light weight, 32 volt, gas engine driven, direct current generator. We needed an alternating current generator and, for ready adaptation to a high voltage transformer which we had found already in production by the Victor X-Ray Company, we required 115 volts. The Delco Company obligingly made changes required in the generator, but the engine did not respond well to having the full

roentgen load thrown suddenly upon it. So I asked for Dr. Kettering's personal assistance. He generously came to Schenectady and spent a whole week with us in so modifying that engine that it would promptly accept the suddenly applied load.

Adapting the Roentgen-Ray Generating Equipment to the Table

Dr. John S. Shearer, then professor of physics at Cornell University, had assumed the responsibility for the design of the "Portable" table and he cooperated closely with us in harmonizing table and roentgen-ray source.

Packaging for Shipment of Tube to the War Zone

Shipment of the tube caused us much worry at first. Our experience was all in favor of a light weight, open-work crate permitting the handler to see the glass, and so making him constantly aware of its fragility. But Army shipping instructions called for a solid crate suspended from the corners of another solid crate and we were told that the tube so packed must stand dropping from a dray onto a stone pavement. We found that our tubes would stand this treatment, but, in the first lot shipped abroad in this way, 40 per cent were broken. We were then permitted to use our fragile open-work crates and, when shipped in this way to the war zone, only 1 per cent were broken.

Development of Oil Immersed Equipment

The fact that the hot cathode tube could be made very small, especially for oil immersion, and could rectify its own current and had a long life and did not need to be seen during operation, made it seem very attractive for installation in the same metal container with the transformer serving as the source of high voltage. In this way it was easy to secure excellent roentgen-ray protection, as well as protection from electric shock. Many small outfits of this type have been used for dental work and other purposes, while larger ones have been used for therapy.

Induction Coil Development

In connection with our work on what might be called a glorified Lenard tube, we had tried to develop the induction coil for very high voltage. Using a mercury turbine interrupter for the primary current, we had succeeded in getting up to 900,000 volts. The difficulties, however, increased rapidly with voltage and it looked very difficult to go much higher by this method.

Break in My Active Experimental Work

In 1932, when I became director of the Laboratory, Dr. E. E. Charlton was made head of our roentgen-ray section and, ably assisted by W. F. Westendorp and others, still holds that position. Since then I have been able to devote much less time to this field, but have had the privilege of being a very interested observer.

The Resonance Transformer and the 1 and 2 Million Volt Outfits

My earlier experience with the induction coil and other high voltage sources has made me very appreciative of the low frequency resonance transformer developed by Mr. Westendorp. This required no iron in the center, thus permitting the roentgen tube to be placed there where it would be electrostatically shielded by the transformer and where the connections between tube and transformer would be very short and also completely shielded.

It has been very interesting to watch the development in Dr. Charlton's section of the 1 and 2 million volt roentgen outfits employing the resonance transformer and compressed gas insulation. By this method it looks practicable to go still higher to perhaps 4 or 5 million volts and with several milliamperes of current.

The Betatron

It has also been a pleasure and a privilege to watch the development of the betatron. After Dr. D. W. Kerst, working at the University of Illinois, had built a successful small machine, giving 2.3 million volt roentgen rays, he procured a leave of

absence from the University and joined our research staff for over a year. While he was here, with the help of Dr. Charlton's group, a larger machine embodying the same principles was designed and built. This operated satisfactorily at 20 million volts. We have since then built a still larger machine of the same type which gives roentgen rays of any voltage from 2 million up to 100 million. The fact that it has been possible to go so directly from Dr. Kerst's first machine to one giving over forty times the voltage would augur well for future further advances in this direction.

Significance of Röntgen's Discovery

During the past fifty years the roentgen rays have indirectly greatly extended our vision. Our eyes respond directly to a region of the spectrum which is only one octave in length. The rays were first produced by Röntgen at perhaps 25,000 volts. Through the years we have gradually worked up to a few million volts and now, with the betatron, to 100 million volts. In the other direction we have gone down to as low as 1,000 volts. The roentgen spectrum available today then covers a range of more than sixteen octaves and indirectly extends our vision to this extent.

The roentgen rays have shown us the relation between the various chemical elements. They serve as a means of chemical analysis. They enable us to measure the distance between the atoms in a crystal and so to determine crystalline structure.

They perform an invaluable service in medical diagnosis and are a powerful therapeutic agent in the treatment of human ills.

They occupy a rapidly expanding place in industry, where they are used to show cavities and foreign inclusions in structural and other materials, to indicate whether vital internal parts of a structure are present and in proper position, and recently as a thickness gauge which does not require contact with the part to be measured.

The very low voltage roentgen rays are used in microroentgenography as a means of studying the composition of very thin metallic specimens and to reveal structure in delicate botanical and zoological tissues. They may be used to produce genetic changes in plants and animals.

Lastly, and to the physicist most important, the roentgen rays have perhaps more than any other single agency advanced our knowledge of the structure of matter.

At the close of these rambling reminiscences I take the opportunity to acknowledge the help and the pleasure which I have derived from the close association which I have had through the years with the many doctors, dentists, physicists, industrialists and others interested in the various uses of roentgen rays.

EARLY AMERICAN ROENTGENOGRAMS

By OTTO GLASSER, Ph.D.
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THE question, "Who made the first x-ray picture in the United States after Röntgen's announcement of the discovery?" has frequently been raised but never conclusively answered. Intimately related to this question is another: "When did news of the x-rays reach the United States?"

Although Röntgen made his first observations on the effects of a new kind of rays as early as November 8, 1895, he talked with no one about the discovery until he handed his first "preliminary communication" to the secretary of the Würzburg Physical Medical Society, December 28, 1895. New Year's Day, 1896, he mailed to certain colleagues reprints of this paper together with copies of his first x-ray pictures. Because of the enthusiasm of some of these colleagues, word of the sensational discovery quickly reached the newspapers, the first report appearing in the Sunday edition of the Vienna *Presse*, January 5, 1896. The next day the news spread to all Continental papers and was cabled throughout the world:

> The noise of war's alarm should not distract attention from the marvelous triumph of science which is reported from Vienna. It is announced that Prof. Röntgen of the Würzburg University has discovered a light which for the purpose of photography will penetrate wood, cloth, and most other organic substances.

Thus, American papers printed news of the discovery at the same time, or even before, it appeared in Röntgen's hometown newspaper, the *Würzburger General Anzeiger*, January 9, 1896. The *Cleveland Plain Dealer*, for example, printed an editorial on the new rays January 9, 1896:

> An Austrian professor has discovered a light, which "makes light" of the most opaque obstruction to the photographic lens, and enables him to photograph boxed metal objects with a draped camera without a trace of the intervening wood and cloth, and broken arms, and bullets in the human body without evidence of the concealing flesh or skin. . . . It is a singular story, but vouched for and explained by the use of certain rays which penetrate organic matter and other opaque substance just as ordinary rays penetrate glass.

Within the next few weeks numerous papers, journals, and magazines published more detailed descriptions. Workers in many laboratories equipped with induction coils and evacuated glass tubes of the Hittorf-Crookes type reproduced Röntgen's results. Just which one was the first to do so is uncertain.

Richtmyer in a report to *Science*, 1932, made the following statement: "It is said that within forty-eight hours after American newspapers had printed the cable dispatch reporting the discovery of x-rays, at least six x-ray photographs had been made in laboratories on this side of the water." A thirteen year study of available information has failed to reveal American roentgenograms definitely dated early January, 1896, or otherwise incontestably identified.

Statements to the contrary must be considered doubtful. One of the best known was made by M. I. Pupin in "From Immigrant to Inventor:" "I obtained the first x-ray photograph in America on January 2, 1896, two weeks after the discovery was announced in Germany." Since the discovery was not announced until early January in Germany and was not cabled to America until January 6, and since cable messages received in the United States before these dates revealed no advance information, I asked Pupin, December 18, 1929, for further information on his early roentgen-ray work. He answered:

The first news of the discovery of x-rays was sent to me by a friend, a physicist in Germany. I also saw an announcement of the discovery in one of the New York papers. All this happened several days prior to January 1, 1896. I have no records to prove this; nothing but memory. I have no copy of my first x-ray picture, and I do not believe that it is possible to obtain one. . . . I am sorry that I cannot help you out with more definite information. But experimental data obtained in my laboratory so long ago are not likely to be recorded anywhere. I never had the habit of keeping data of a certain piece of experimental work after the work was finished and published.

"Roentgen Rays," Pupin's first report on his experiments, was written February 8 and published in *Science* (Vol. 3, p. 231) for February 14, 1896. It seems very likely that Pupin made his first x-ray picture February 2 instead of January 2 which was approximately "two weeks after the discovery was announced in Germany." It is entirely possible, however, that Pupin's roentgenogram was one of the first made in the United States.

Similar uncertainties cloud other reports of early roentgenograms in this country. This situation is complicated by the fact that the first x-ray photographs were made by physicists and photographers. Some weeks passed before physicians availed themselves of this new diagnostic method. Yet naturally, from their point of view, they considered their efforts with the newly discovered rays the earliest ones.

Historical study indicates that the earliest roentgenograms in the United States and Canada were made by the following scientists: F. Cajori of Colorado College, Cox of McGill University in Montreal, T. A. Edison and his assistants, E. B. Frost of Dartmouth College, D. W. Hering of New York University, A. W. Goodspeed of the University of Pennsylvania, T. J. Houston, E. C. Jerman of Chicago, A. E. Kennelly, E. Merritt and G. S. Moler of Cornell University, D. C. Miller of Case School in Cleveland, C. L. Norton of Boston, M. I. Pupin of Columbia University in New York, Dr. Henry Louis Smith of Davidson College, J. P. C. Southall of Miller Training School of Albemarle in Piedmont, W. M. Stine of the Armour Institute of Technology, J. Trowbridge of Harvard, and A. W. Wright of Yale University.

While collecting material for my Röntgen biography, I had the good fortune to have advice and information from many of these early American roentgen-ray pioneers. Nothing illustrates better their interest in the new discovery and their diligence in working it out than quotations from their original letters. These statements also throw light on the difficulty of determining who took the first roentgenogram in the United States.

F. Cajori of the University of California claimed that he and a colleague were the first in Colorado to show roentgen-ray effects. On January 12, 1930, he wrote:

As I remember, the news of the discovery of x-rays reached me in Colorado College, just as I was completing the MS to my "History of Elementary Mathematics," December, 1895. I remember taking the MS on my bicycle down to the express office, and, the same evening starting in with my good friend, Professor William Strieby, to try for x-rays. I had at Colorado College a fairly good Ruhmkorff coil and a few Crookes tubes. We got some shadows of vegetable substances that evening, which we were inclined to consider due to other than x-ray effects. The next day we got the first shadows from metallic plates. . . . We were the earliest in the State of Colorado to show the x-ray effects.

Records and publications proved that Henry W. Cattell of Philadelphia worked with roentgen rays as early as February 1896. On December 21, 1929, he wrote:

My work was sent out first by associated press dispatches, before being published in February, 1896, in the *Medical News* and in the *International Medical Magazine*. I have my first records.

In a second letter, February 5, 1930:

I coined the words skiagraph and skotograph. . . . I had, as far as I know, the first portable x-ray outfit in America; I went to Queen's and

bought up all the Geissler and Crookes tubes they had, and my first exposures seen in the *Medical News* of February 15, 1896, took twenty minutes to half an hour.

In a third letter, April 1, 1933:

I still have the things that I had in my portable x-ray apparatus in January, 1896. . . . When I made the skiagraphs in January, 1896, I had never seen a Roentgenogram, and naturally they are very crude.

William H. Dieffenbach of New York wrote on January 8, 1935, that a roentgenogram of his hands was the first taken in the United States:

In January, 1896, I was a student with Dr. William Hardey King who had a large static machine in his office. When I called his attention to an article in the *Literary Digest* of January, 1896, telling of Röntgen's new discovery, Dr. King secured a Crookes tube and hitched it to the static machine and tested out the radiation on my hands—exposing same for several minutes. I had the plate developed at a nearby photographer's, and this was, I believe, the first plate taken in the U.S.A. The date is fixed in my mind as the middle of January, 1896.

Edwin B. Frost of Dartmouth College began his experiments with roentgen rays the last of January, 1896. On January 24, 1930, he wrote:

On the basis of fragmentary news that was published in American newspapers by cable from Germany, I began experimenting in the Physical Laboratory of Dartmouth College in the last days of January, 1896; but I cannot now state positively whether my first picture was obtained on Saturday, January 24, or February 1. I had my article for *Science* finished on February 4, and it was published ten days later, along with articles by M. I. Pupin, and A. W. Goodspeed, whose papers are dated four days later than mine.

In a Cornell University museum, E. Merritt discovered evidence of his early work in roentgen rays. A letter from him on September 26, 1929, states:

I find in our department museum three early x-ray pictures, two made by Professor Moler and one by myself. Those made by Professor Moler are shadow pictures of various metal objects like keys and chains which had been placed inside of a pasteboard box and then photographed. Our records do not show the exact date, but Professor Moler had written on the back of them that they were taken after the news was received of Röntgen's discovery, but before Röntgen's first pictures had arrived.

Dayton C. Miller of Case School of Applied Science realized that his early roentgenograms were not dated and cannot be claimed as the earliest ones. He said on February 20, 1933:

In January, 1896, cabled news appeared announcing Röntgen's discovery of the x-rays. The Physical Laboratory of Case School had purchased the complete set of Crookes tubes which had been exhibited by the firm of Geissler of Bonn, Germany, at the World's Columbian Exposition, Chicago, 1893. Experiments were begun immediately, and several tubes were found which produced x-rays. . . . We first succeeded in photographing some inanimate objects. Then we photographed the hands of Mrs. Miller, and this was published in the newspapers. We think that this picture was the first one in this part of the country, but let me say that it was perhaps taken in the same week as pictures taken at Columbia University, University of Pennsylvania, Bowdoin College, Amherst, Harvard, and many other places. Many of these early pictures were not dated so that they cannot claim to be the earliest one.

Yet P. C. Southall of Columbia University claimed that his were the first roentgenograms made in this country. On December 20, 1929, he wrote:

In the year 1895 I was the head of the Department of Physics and Mathematics at the Miller Manual Training School of Albemarle in Piedmont, Virginia. I had a beautiful collection of Crookes tubes and every facility for doing this kind of work, when a meager report of Professor Röntgen's discovery was cabled to this country. I read an account of it in the newspapers, and a day or two later I had succeeded in obtaining x-ray radiographs of coins and a bunch of keys. As far as I know, these were the first x-ray photographs that were ever made in this country.

W. M. Stine of Pennfield, Pa., in a letter of July 10, 1930, told of the success of his colleague, A. A. A. Atkinson:

As I was resuming my experiments for the third time, there came the news of Röntgen's discovery. . . . I lost no time in sending to my successor at the Ohio University at Athens, Professor A. A. A. Atkinson, precise directions for setting up the apparatus exactly as I had had it for my first experiments. He explicitly followed my directions and was immediately successful.

Experiments were begun by D. W. Hering of New York University the first of February, 1896. He wrote on December 24, 1929:

New York University was fortunate in possessing a fine set of Crookes tubes, such as were then supplied from London for the repetition of Professor Crookes' remarkable experiments with cathode discharges in high vacua, but our only means of exciting them were an induction coil producing a spark of scarcely three inches in air and a good Toepler-Holtz plate machine giving a spark of six to eight inches. . . . I began experimenting about the end of January or the beginning of February, 1896, and began to get pictures in the first week of February.

C. C. Hutchins of Brunswick, Maine, made and used roentgen-ray tubes of his own soon after news of the discovery. This he reported in a letter of December 20, 1929:

As soon as the news of the discovery reached America I overhauled my collection of Crookes tubes, selected the most suitable one and therewith made a photograph of a single finger of Dr. G. M. Eliot, a local physician. There happened to be in my laboratory a very good mercury pump, and I happened to be a pretty good glassblower, so I set to work on x-ray tubes of my own, with success from the first. . . . As I now remember I had these tubes in use inside of two weeks of the arrival of the news of the discovery.

The shipment of a Crookes tube held up Ed C. Jerman's experiments. As he said on August 29, 1930:

When Röntgen's paper was broadcast to the world the latter part of December, 1895, and during January of 1896, first through the lay press and quickly followed by the scientific press, I quickly found that I had all the equipment necessary for producing the x-rays except a Crookes tube. I finally succeeded in getting a Crookes tube, imported through Oelschlaeger of New York. I received this tube in March, 1896, and my first successful exposure was made with a small Pattee two plate static machine.

A. E. Kennelly of Harvard University studied the new rays with Edison in January, 1896. On December 26, 1929, he wrote:

When the news of the new roentgen rays reached America by cable early in January, 1896 Mr. Edison took up their study, and invited me to see some of his experiments at his Orange laboratory. I spent from January 27 to February 2, 1896, with him. . . . Professor Houston and I had already repeated in a crude fashion a few of the Röntgen experiments, as announced by cable, in our laboratory at Philadelphia, using an induction coil and a few Crookes tubes that were purchasable in Philadelphia. We had obtained x-ray pictures on ordinary photographic plates of coins, keys and similar objects.

R. H. Lafferty of Charlotte, N. C. verified his early experimentation with roentgen rays by a print from his first plate. In a letter of June 18, 1931, he said:

Osmond Barringer, Eben Hardie and Pender Porter of Davidson College, on Sunday night, January 12, 1896, slipped into the laboratory and made a picture on a kodak plate. It required about three hours' exposure. . . . The only corroboration that I have of the date, January 12, 1896, is: first, that I recall the event as coming quite soon after our return from our Xmas holidays; second, I do not have the plate that was made but did have the print from which a cut was made; on the back of this was the date, January 12, 1896. This plate is now in the Archives of Davidson College.

W. H. Meadowcroft of Orange, N. J. reported that Edison began experiments immediately. On January 25, 1930, he wrote:

Mr. Edison opened your letter and asked me

to say to you that within two days after the original announcement of Dr. Röntgen was cabled over from abroad, he, Mr. Edison and his assistants commenced experimenting along the lines indicated in the cable from abroad. In four days Mr. Edison had achieved the same results.

A. W. Goodspeed of Philadelphia claimed accidental discovery as early as 1890. In his letter of February 15, 1929, he wrote:

My early articles on "Roentgen Rays and their Applications" were published in the *Proceedings of the American Philosophical Society* in January, 1896, and in *Science*, February 14 and March, 1896.

The accidental roentgen rays' effect which W. N. Jennings of Philadelphia and I produced in 1890 was real and authentic. Because of our laxity in not following the matter up we do not claim any credit whatever but the facts are as stated in such articles as you may have read.

It seems to be impossible to state with certainty who took the first roentgenogram in the United States. However, this question becomes somewhat academic in view of the tremendous interest with which Röntgen's discovery was received and quickly repeated in many laboratories in this country.

THE ROENTGEN EXAMINATION IN OCCUPATIONAL DISEASES OF THE LUNGS

A HISTORICAL DISCUSSION OF ITS USE*

By EUGENE P. PENDERGRASS, M.D.
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PNEUMOCONIOSIS is a generic term used to describe all forms of pulmonary reactions to dust lodging in the lungs. These changes may or may not be demonstrable by the roentgen examination. Other terms such as siderosis and anthracosis are special names which serve to indicate the lung condition occurring in certain industries (iron and coal mining).

It is generally conceded that the roentgen examination of the chest, carefully done, is the most precise method at our command for demonstrating physical shadows of pathological changes in the lungs produced by some dusts. Unfortunately, there are many other conditions that produce shadows in the roentgenogram which may simulate some of the various shadows found in pneumoconiosis. I always have regarded the roentgen examination as a consultation, and used as such it is likely to be more valuable. It, therefore, behooves those of us who utilize chest roentgenography to consider all of the various lesions that may produce lesions simulating pneumoconiosis before arriving at a diagnosis; otherwise mistakes will be made.

In a review of the literature on pneumoconiosis from 1895 to 1899 I found only one article in which roentgenography was employed. A French physician, Oddo,[34] reported a case of anthracosis in a male, aged fifty-eight, in whom a roentgen examination of the chest showed multiple shadows in both lungs (sclerose pulmonaire) which were interpreted as anthracosis. An autopsy substantiated the diagnosis of anthracosis (Fig. 1).

In preparing this historical review, I have had occasion to peruse essentially all of the early English, German, and French radiological periodicals. Many of these were on general subjects but I was impressed with the comparatively few publications on the roentgen diagnosis of conditions involving structures within the thoracic cavity. This was not true of the American literature, however. The early publications of Williams, Caldwell, Newcomet, Crane, Kassabian, Hulst, and many others, were most noteworthy. The most comprehensive treatises on the chest were probably those of Crane and Williams, and it would be most stimulating and enlightening for all radiologists to search out the publications of these and other authors in order to learn how careful were the observations in those early days of our specialty.

In Williams' book, "The Roentgen Rays in Medicine and Surgery," he devotes eleven chapters to the chest, excluding the esophagus. There are 757 pages in his book, and 297 pages are allotted to chest diagnosis. When one looks at more recent publications, one cannot but admire the foresight of Dr. Williams. The chapters devoted to chest diagnosis are as follows:

Chapter III. *Methods of Diagnosis.* Williams discusses the use of the fluorescent screen and the roentgenogram.

Chapter IV. *Introduction to the Thorax.* In this chapter he discusses the appearance of the heart, the lungs, and the diaphragm in the healthy chest.

Chapter V. *Pulmonary Tuberculosis.* This is a long chapter devoted to the diagnosis of early tuberculous lesions and the comparative value of the fluorescent screen and roentgenogram in diagnosis. He calls attention to the value of making roentgen examinations from time to time in persons from fifteen to thirty years of age if there is a family history of tuberculosis. Williams stated: "In this way, . . . early warning

* From the Department of Radiology, Hospital of the University of Pennsylvania.

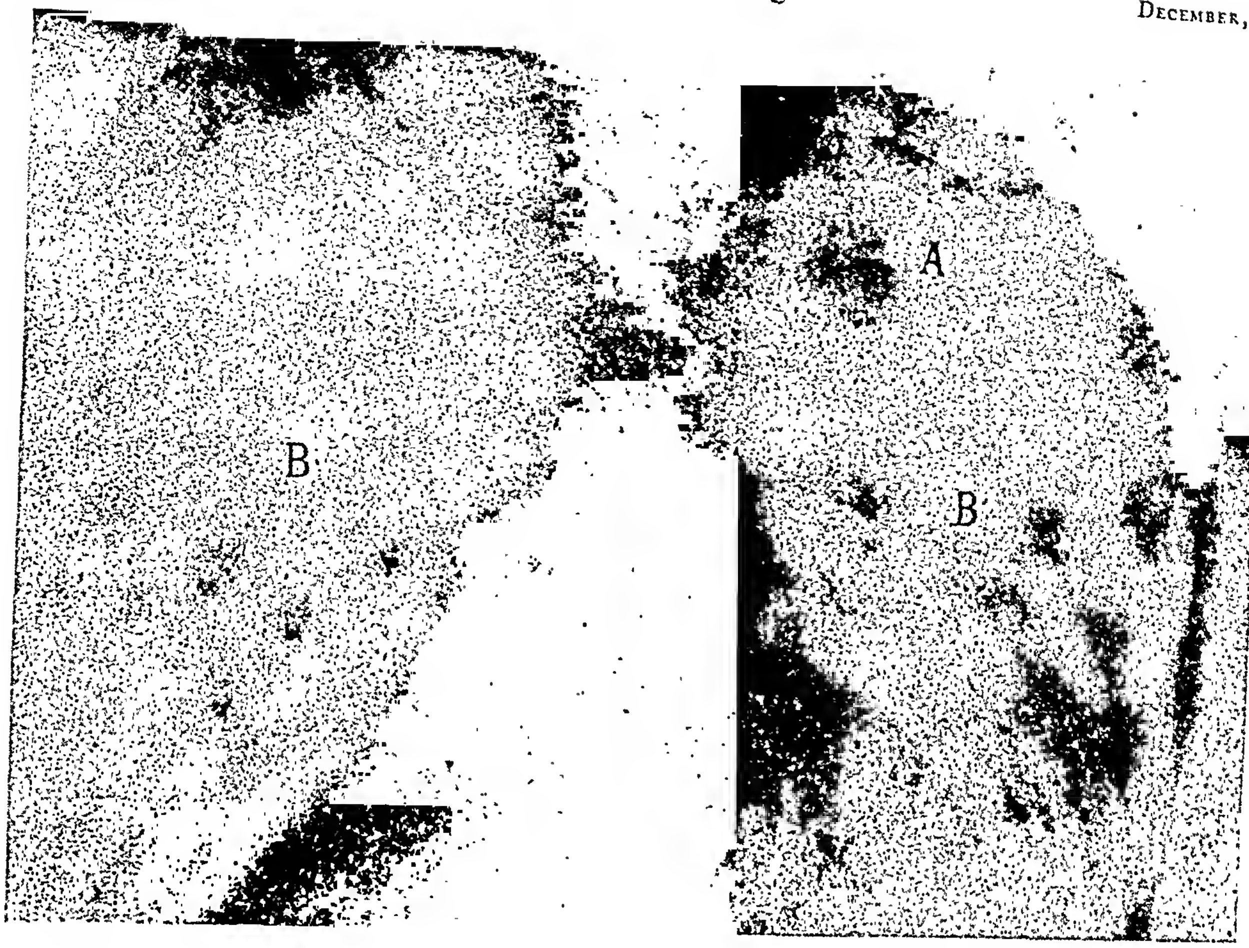

FIG. 1. Illustration taken from Oddo,[34] published in 1899, showing what he described as "sclerose pulmonaire" in a case of anthracosis.

would be given, and the best opportunity for its arrest obtained." He called attention to the greater accuracy of the roentgen examination over that of auscultation and percussion, and the frequency with which the roentgen diagnosis was confirmed by autopsy. He discussed acute and chronic tuberculosis, tuberculosis complicated with other diseases, tuberculosis with effusions and cavities.

In the concluding paragraph of this chapter Williams makes the following statement:

All who are experienced in making physical examinations of the thorax recognize the necessity of controlling one method of examination with another. Not infrequently we understand best the conditions present, as just suggested, by taking into consideration the information obtained from inspection, percussion, and auscultation together, and if we fail to do this we may err in our diagnosis. The x-rays give another and valuable method for controlling the results obtained in other ways, and also add to them. We may, by their use, not only control one method by another, but with the eye supporting the ear we also control one sense with another.

Chapter VI. *Pneumonia.* Williams, in pneumonia, as in tuberculosis, used the roentgen examination of excised lungs as a basis for developing his diagnostic criteria. Frequent examination with drawings of screen observations demonstrated the progression and regression of the lesions.

Chapter VII. *Emphysema of the Lungs. Bronchitis.*

Chapter VIII. *Pleurisy with Effusion, Emphysema.*

Chapter IX. *Hydrothorax. Pneumothorax. Empyema with Permanent Opening. Pneumohydro- or Pneumopyothorax.*

Chapter X. *Normal and Abnormal Heart.* This is a magnificent discussion and the author emphasizes the value of following the results of treatment by roentgen examination.

Chapter XI. *Thoracic Aneurisms.*

Chapter XII. *New Growths. Enlarged Glands. Abscess and Gangrene of Lung.*

Chapter XIII. *Conclusion of Thorax.*

I feel quite sure that the relative rarity of the clinical suspicion of pneumoconiosis and other occupational hazards and the frequency of tuberculosis in Boston accounts for the lack of consideration given by Williams to the subject of pneumoconiosis.

Among the foreign authors in this period who had contributed to the advancement of chest diagnosis by roentgen methods, Bouchard, Béclère, Benedikt, Rieder and Rosenthal, Levy-Dorn, and Weinberger are especially noteworthy.

During the period of 1910–1920, the development of thoracic roentgenology was marked by increasing use of stereoroentgenography.[9] Concerted efforts were made to classify and standardize the shadow-complex of various lesions, especially tuberculosis. It was during this period that Rieder and Rosenthal, Entin, Boardman, Pancoast, Miller and Landis, and Lanza and Childs recorded the roentgen manifestations of pneumoconiosis.

Since 1920, many publications have appeared describing the roentgenopathologic manifestations of lesions in the lungs resulting from occupational hazards.

SOURCES OF DANGER

Gases.[59] In various industrial operations a number of gaseous products are used or liberated, which may have an injurious effect on the respiratory apparatus. Among others are the halogens (chlorine, bromine, iodine) and their combinations with hydrogen (hydrochloric and fluorhydric acids), sulfureted hydrogen, ammonia, chloride of ammonia, nitric acid and the so-called "nitrous" fumes, sulfur dioxide, phosgene, acetic acid, formaldehyde, acrolein, and fumes from smoke. These same gases, as well as such intermediary products as cyanide of phosgene, fluorine of dimethylarsine and of diphenylarsine, and sulfide of dichlorethyl, are chiefly met with in war gas factories.[59]

Dust. While the physical and chemical laws which control gases are accurately known, the physical properties of the various kinds of dust which constitute industrial dust are far from being defined. There are many classifications of dust recorded, but I shall include only two.

Thompson classified dusts as (*a*) *insoluble inorganic dusts* (irritating the respiratory passages), such as flint, silica, sand, carbon (coal, soot), brick dust, marble, granite, terra cotta, cement, asphalt, enamel, glass, quartz, lime (gypsum, plaster), meerschaum, phosphate (fertilizers), guano, emery, diamond dust, metal filings (lead, brass, iron, steel, etc.), pumice, and ashes; (*b*) *soluble inorganic dusts* (apt to be swallowed and absorbed), such as soluble arsenic, mercury, lead and silver compounds, metal filings of lead, brass, and zinc; (*c*) *organic dusts and fibers* arising from handling or manufacture of wood, bone, and shell, from fur, skins, hides and leather, feathers, brooms and straw, flour and grain, jute, flax (linen), hemp, cotton, wool (worsted, etc.), tobacco, felt, carpets, rags and paper, horsehair, and street sweepings.

Schürmann[54] differentiated dust, according to origin, into animal, plant, and mineral dust and dust from the artifacts. *Animal dust* is evolved with the working of ivory, horn, whalebone, bones, mother-of-pearl, hides, leather, bristles, sheep's wool, hair (horse, rabbit, and cow), and feathers; *plant dust* has its origin in industries working with grain, medical powders, spices, cotton, hemp, jute, flax, tobacco, wood, thick-shelled nuts, bark of plants (tanning industry), rags, shoddy, and paper; *mineral dust* is formed in the working of hard coal, marble, and other limestones and in connection with clay and porcelain industries, also pumice, sandstone, granite, and slates; *dust from artifacts* is found in the glass, glazing, enameling, tile, cement, Thomas slag, celluloid, iron, steel, bronze, galalith, and lead-alloy industries and in the chemical (especially dye) industry. He defined mixed dust as a mixture of polish-

ing materials and the fragments of the object being polished.

Drinker states that these classifications are without much practical importance, since in daily practice in industry the harmful effect is exercised more frequently by dusts mostly of mixed origin. Besides, what is most important is the physical and chemical constitution of the dusts and consequently their action on the system. An effort has been made to group under the heading "inert" a certain number of dusts; the number, however, is becoming more and more reduced since certain dusts, such as talc and asbestos, until recently considered as inert nevertheless have caused serious organic lesions among certain classes of workers. The majority of experts admit that the so-called "inert" dusts are not really inert when considered from the pathogenic point of view. Although at the outset they are not harmful and even when present in the workroom in large quantities some of them cause only transitory discomfort (sneezing, watering of the eyes, cough), it is certain that as the organic reactions diminish and the system seems to have recovered from the effects, they nevertheless finally attack it in a subtle manner, sometimes even seriously. The mucous membrane of the nose, the conjunctiva, and first the upper and subsequently the lower respiratory passages, the teeth, the skin, and often the digestive tract are subjected to the harmful action of these dusts.

With the development of new industrial processes new dust hazards present themselves; thus it behooves the industrial physician, the experimental physiologist, the chemist, the experimental pathologist, the pathologist, the clinician, and the roentgenologist to be constantly on the alert for changes which may be produced in the respiratory tract as a result of tissue reaction to inhaled dusts. Today, there are several lung conditions that are alleged to be due to occupational dusts in relatively new industries, which are not understood clearly, and about which no medical publications have appeared as yet.

A typical occupational disease is the pneumonia which attacks workers who handle basic slag as well as farm laborers who scatter it on the fields.[59]

Various writers have attributed primary tumors of the bronchi and of the lungs to the inhalation of dust. "Schneeberg disease"—pulmonary cancer from which the workers in the cobalt mines of Saxony suffer—is regarded as an occupational disease, although the etiology is not yet clearly established. In the United States it appears that cases of carcinoma of the lung have been observed among petrol refiners and that this resembles the cancer of the skin caused by paraffin.[59]

The problem of occupational asthma is reported to be the same as that of occupational anaphylaxis.[59] In many of the cases the occupational character of the disease is clearly defined. The anaphylaxis is caused by the pollen of gramineous plants, dust from threshing oats, from hackling hemp and flax, from jute or cotton when opening the bales, or from flour, causing millers' and bakers' asthma.

Cases of asthma of the same variety have been observed in chemists and upholsterers, caused by such chemical products as aspirin, arsenobenzoles, ipecacuanha or lead, as well as in persons who come in contact with dust of animal origin, such as feathers, down and animal scales and hairs. In the case of furriers who use "ursol," asthmatic attacks as a rule appear only in those who prepare or handle black furs, after several years of work, during which they may have experienced no ill effects. Simultaneously or independently of the asthma, cutaneous lesions may make their appearance—urticaria, acute and chronic eczema and erysipeloid forms, which have also been found in persons who wear furs dyed with "ursol."[59]

Cases of asthma have also been observed in florists, horticulturists and fruit pickers; they may also be accompanied by pruriginous dermatitis, and these cases are based on allergy acquired by the inhalation of vegetable dust, which often contains an *Acarus*,

Pediculoides ventricosus, its secretions and excretions.[59] Silk-spinners' asthma, caused by handling silkworms' cocoons (*Bombyx mori*) is accompanied by inflammation of the eyes and a pruriginous dermatitis (mal des bassines.)[59]

In the pneumoconiosis caused by soot, which is found among coal miners, chimneysweeps and stokers on trains, the lungs are very black, but are free from sclerosis. In the pneumoconiosis due to wood charcoal the lungs are not thickened, which is also the case with coal miners' lungs when the seams do not penetrate hard rock.[59]

Free silica and asbestos dusts are the most hazardous of all of the industrial dusts. The two clinically important forms of pneumoconiosis, silicosis and asbestosis, are due to these two dusts.

Experimental investigations have shown that most non-siliceous dusts exert no appreciable effects on connective tissues, the reaction is not progressive and does not terminate in a fibrosis appreciable on gross examination. It would seem, therefore, that if abnormal shadows are observed in roentgenograms of individuals exposed only to non-siliceous dusts some other condition is present.[48]

There are conditions known chiefly from the shadows they produce on the roentgenogram. These conditions such as baritosis, and the "false nodulation" of arc welders, are known as benign penumoconiosis.

The nonspecific pneumoconiosis due to reactions of the lung tissues to organic dusts are more important from the clinical than from the roentgenologic standpoint.[15] Oftentimes byssinosis (pneumoconiosis due to cotton fiber) may be present and not demonstrable by the roentgen examination. In general, it is assumed that most of the organic dusts may cause bronchitis with or without sensitization phenomena resulting in a variety of allergic symptoms.[15]

The diagnosis of silicosis and asbestosis is not easy. Even though the roentgen examination provides the best method of investigation, the diagnosis of pneumoconiosis should be made only by an experienced physician, exercising keen clinical judgment based upon a consideration of the present and past occupational history, past medical history, present complaints, and the clinical manifestations revealed by a thorough physical examination correlated with the laboratory reports and the roentgen examination of the chest.

There is so much on the subject of pneumoconiosis, it has seemed best to select for recording here a few of the investigations that have been carried on in the various countries to illustrate the extent of the hazard.

GREAT BRITAIN

England early recognized the importance of occupational diseases of the chest. In 1862, a commission was appointed to inquire into the health of men employed in metalliferous mines.[10] During the ensuing years, some of the most important experimental and pathological investigations were presented by English workers. However, there were very few clinical reports that emphasized the importance of the roentgen examination.

As late as 1934, Harper, a radiologist practicing in the South Wales coal fields, in a letter to the *British Medical Journal* said that more colliery men in South Wales had chest roentgenograms than in other places. This he thought was the reason for the high incidence of silicosis in his district. He felt that a similar experience would obtain elsewhere if more general use of the chest roentgenogram was employed.

In 1930 Merewether and Price and later Merewether reported on their studies in asbestos. These publications have greatly stimulated work in this recently discovered occupational disease. Later Sparks, and Wood and Gloyne made an effort to determine whether pulmonary asbestosis, like silicosis, paves the way for a tuberculous invasion.

AUSTRALIA

The rapid increase in Australia's population in the latter half of the last century was

due in large part to the discovery of rich alluvial gold fields in several parts of that continent. This stimulated prospecting and brought about the discovery of other metalliferous deposits. A large portion of the migrants came from mining districts in England and other countries.

Silicosis has been demonstrated in many of the mining fields and a high death rate from pulmonary diseases, including tuberculosis, has been evidenced in connection with the industry.

In 1919, in a study of the miners at Broken Hill the roentgen examination of the chest as a means of diagnosis of silicosis as an occupational disease was employed for the first time.[17] Again in 1922 the New South Wales Board of Trade utilized the roentgen examination in a study of the sandstone and siliceous rock workers of Sydney.

CANADA

Pneumoconiosis or silicosis or miner's phthisis has been scheduled as a compensable occupational disease in quarrying, stoneworking, metal grinding or polishing, and mining, for a number of years in Ontario, Alberta, and Saskatchewan.[53]

Silicosis has been studied from time to time in the gold fields of Ontario, at Porcupine, Kirkland Lake, Cobalt, and Sudbury. Granite cutters in Ontario were examined in 1928. Other examinations have been made among foundry workers and among sandblasters, as well as workers in marble talc, cement, brick, grain elevators, and artificial abrasives. These investigations were carried out by the Industrial Hygiene Division of the Ontario Health Department, where Cunningham, Riddell, and their associates, have done work on correlating clinical, roentgenological, and pathological findings in lungs of workers.

GERMANY

In Germany there has been considerable interest in the subject of pneumoconiosis.

Staub-Oetiker described the roentgen appearances of sclerobic lung as found in metal grinders and recorded, as have so many others, various stages of the disease. Ickert and many other German authors have discussed in detail the part that silica alone plays in the production of fibrosis and when complicated by tuberculosis. Many of these investigators emphasize that silica may produce considerable fibrosis without the agency of tuberculosis.

German authors more than others have contributed to the literature concerning the finding of cancer of the lung associated with pneumoconiosis. The Schneeberg miners were apparently the earliest workers in which cancer was recorded as a complication of pneumoconiosis. Davis *et al.* have included an excellent bibliography on this subject in their book.

ITALY

Italy has a rich heritage in pneumoconiosis which extends back to the clinical and anatomical observations of Ramazzini.

Bianchi has utilized the roentgen examination of the chest in his investigations of sculptors, hewers, modelers, and workers in grinding rooms.

It was in Italy that the interesting condition, baritosis, which is one of the benign pneumoconioses, was found among baryta ore workers and reported by Arrigoni.

NETHERLANDS

The roentgen examination of the chest was employed in 1923 in studying some of the stonemasons, and it was noted by Kranenburg that the roentgen examination was more accurate than any of the other methods employed.

SOUTH AFRICA

Great credit should be given to the South African investigators for their contributions to the subject of pulmonary dust diseases. Even though the roentgen ray was discovered in Germany and her pathologists had made notable contributions, it was in South Africa in 1911 that chest roentgenography was for the first time employed on an extensive scale.[45]

The reliance placed upon chest roentgen-

ography was well expressed by Watkins-Pitchford, chairman of the South African Miners' Phthisis Medical Bureau. He states that it is not safe to venture upon a positive diagnosis of silicosis without the assistance of "a technically satisfactory radiograph," which is so essential in all diagnostic roentgenograms of the lung. Steuart, roentgenographer for the South African Bureau at the time of his report, had 200,000 chest roentgenograms of 57,000 individuals in his files.

Very few reports of asbestosis have come from South Africa.

UNITED STATES

Although the United States was late in getting started in the field of investigation of occupational diseases of the chest, there are today more exhaustive studies being carried out in this country than any other place in the world. Particularly is this true in chest roentgenography. Lanza and Childs and my own former chief, Dr. Pancoast, are probably responsible, more than anyone else, for the early enthusiasm that was created for including roentgen studies of the chest as a part of any comprehensive investigation of occupational diseases of the chest.

The industrial processes in the United States are extremely varied. There are many dusts which modify the action of silica and silicates, so much so, that it is essential for one to be familiar with the industrial operations in order to interpret properly the pattern of the changes produced on the roentgenogram by the pathological process.

In this country, chest roentgenography has been included as a part of studies of the chest in workers in the following industries: abrasive, aluminum, asbestos, sand blasters, brick, cement, ceramics, clay, coal (hard and soft), copper mining, foundries, gold miners, granite, grinders, gypsum, iron, lead, marble, porcelain, pottery, quartz and sand, slate, spray painting, stone, tobacco, wood, and zinc industries.

There are many other workers such as arc welders, tin and beryllium workers in whom there are interesting roentgen findings.

At the present time, data are not available on the general incidences of occupational diseases of the chest in this country. Even with silicosis and asbestosis, the incidence would be difficult to obtain from our vital statistics. In most of the large and in a few of the small industries, however, the industrial physician is on the alert about occupational conditions in the chest. Likewise, Federal and State agencies are being requested with increasing frequency to make health surveys of workers in various industries. It is hoped, therefore, that in the not too distant future, reliable information concerning the incidence of occupational chest conditions will be forthcoming from our vital statistics.

In 1917, Lanza and Childs presented the first American classification of stages of the condition based upon roentgen findings. This has stood the test of time so far as appearances are concerned, although there have been some changes in opinion as to the pathological features. They divided the progress of the condition into three stages, which may be briefly described as follows: *First stage:* The root shadows are denser, and more extensive, and may show nodules; the trunk shadows are increased in density and breadth, with numerous punctate deposits of varying size along them; the appearance is symmetrical on both sides at first, but not so later; there is no difference in diaphragmatic excursion. *Second stage:* In addition to the foregoing, there are found fairly symmetrical, small, circumscribed, dense areas throughout both lungs, and later larger masses accumulate, usually at the lower part of the upper third, about the level of the root shadows; the domes of the diaphragms seem accentuated. *Third stage:* This differs from the second only in the extent of lung involvement, indicated by increased numbers of deposits and more massive grouping. Lanza and Childs then go on to describe more advanced fibrotic changes, with

heart, vessel and tracheal displacement and restricted diaphragmatic excursion which they were inclined to ascribe to a tuberculous complication which we now know may be due entirely to advanced silicosis, although tuberculosis may be a factor. This classification, with a few minor changes, answers the purpose admirably today.

During the same year, Pancoast, without any knowledge of the work of Lanza, developed a similar classification, differing only in minor details. However, since this classification was not in general use, Pancoast and Pendergrass suggested the following pathologic-roentgenological classification to overcome existing confusion:[40]

1. Peribronchial-perivascular-lymph node predominance {rapid, slow}
2. Early interstitial predominance (Interferes with diaphragmatic movement) {with nodular appearance, without nodular appearance, rapid or slow}
3. Late or advanced interstitial predominance
4. Nodular predominance {non-progressive, progressive}
5. Advanced diffuse or terminal fibrosis {conglomerate nodular type, interstitial type, massive fibrosis type}

This classification is most satisfactory from the standpoint of uncomplicated silicosis, but it has never become very popular among physicians interested in this subject.

A later classification suggested by an interested committee[44] is as follows:

It should be distinctly understood that the tabulation which follows applies only to *silicosis*, that form of pneumoconiosis resulting from the inhalation of dust with a high silica (SiO_2) content. Other forms, like asbestosis, are excluded from this consideration because their pathology is essentially different from that of silicosis.

The tabulation contains two columns: on the left are the roentgenological appearances and on the right are the corresponding pathological lesions. There is further subdivision to describe the appearances of (1) healthy lungs, (2) the uncomplicated silicotic lung, and (3) lung of silicosis *with* infection. The changes described under the first division are those compatible with a state of good health; and while they *may* be produced by the inhalation of relatively small amounts of silica dust, they are not sufficiently characteristic or advanced to substantiate a diagnosis of silicosis. Similar or identical appearances may also result from the inhalation of non-siliceous dusts, from certain infection, from cardiovascular disease, and from certain other rare conditions. The changes involved are for the most part confined to the lymphatics and perilymphatic connective tissues and do not affect the parenchyma of the lung. Since, by definition, silicosis is a disease characterized by nodular fibrosis in the parenchyma of the lung, these alterations, even when they may have been caused by inhaled silica, do not constitute a basis for a diagnosis of silicosis. The second group covers the discrete and conglomerate nodular fibrotic reactions of simple silicosis. The last group deals with silicosis complicated by infection. In the majority of instances the infecting organism is the tubercle bacillus, but the classification is sufficiently broad to include other types of infection. Certain criteria by which one attempts to differentiate various forms of infection will be discussed.

Roentgenological appearances	Histological appearances
SIMPLE SILICOSIS	
1. Nodulation.—Discrete shadows not exceeding 6 mm. in diameter, tending to uniformity in size,	1. Circumscribed nodules of hyaline fibrosis located in the parenchyma of the lung. Occasionally some

Roentgenological appearances	Histological appearances
density, and bilateral distribution, with well-defined borders surrounded by apparently normal lung shadow. The outer and lower lung fields characteristically show fewer nodules.	of these nodules may show microscopic foci of central necrosis.
2. Conglomerate shadows that appear to result from a combination or consolidation of nodulation usually with associated emphysema manifested by— a. Localized increased transparency of the lung with loss of fine detail. b. Intensification of the trunk shadows by contrast. c. Depression of the domes with possible tendency toward individualization of the costal components of the diaphragm. d. Lateral view: Increase in the preaortic and retrocardiac space with exaggerated backward bowing of the spine. Widening of the spaces between the ribs may or may not be present.	2. The result of coalescence of discrete nodules; an area in which the nodules are closely packed and most of the intervening lung is replaced by more or less hyaline fibrous tissue. The lung architecture is partially obscured. No demonstrable evidence of infection. Emphysema is a compensatory dilatation of the air spaces with or without thickening of the septa.

SILICOSIS WITH INFECTION

The characteristic appearances described under simple silicosis are modified by infection as follows:

Roentgenological appearances	Histological appearances
3. Localized discrete densities and/or string-like shadows accompanying those of simple silicosis described above.	3. Strands of fibrous tissue, often along trunks and septa, with or without areas of calcification; indicative of "healed" infection.
4. Mottling.—Shadows varying in size with ill-defined borders and lacking uniformity in density and distribution, accompanying simple silicosis.	4. a. Areas of bronchopneumonia with or without caseation, i.e., acute infection. b. Lobular areas of proliferative reaction with or without caseation, i.e., chronic infection.
5. Soft nodulation.—The nodular shadows described under simple silicosis have now assumed fuzzy borders and/or irregularities in distribution. This change may or may not accompany simple mottling.	5. Perinodular cellular reaction either exudative or proliferative in character.
6. Massive shadows of homogeneous density not of pleural origin symmetrically or asymmetrically distributed.	6. Extensive areas of fibrosis probably due to organized pneumonia of tuberculous or nontuberculous origin superimposed upon a coexistent silicotic process. Outlines of normal structures may be partially destroyed.

COMMENT

For the first group of appearances we have adopted the nomenclature of the National Tuberculosis Association Committee and described the lungs as *healthy* rather than *normal*, as a perfectly normal adult human being is a great rarity. For a description of the roentgenological appearance of the healthy chest the reader should consult a paper by Pancoast, Baetjer, and Dunham in the American Review of Tuberculosis for 1927, vol. 15, pp. 429–471.

As already mentioned under 2, *Irregular exaggeration of the linear markings, with possibly some beading*, belongs in the healthy chest group even when found in persons with a history of considerable exposure to silica, for such changes are nonspecific in character and they do not involve the parenchyma of the lung. Silicosis as a clinical disease begins only when the lung proper is affected. Likewise, under 3, *Increased root shadow* may be of nonspecific origin and hence is not diagnostic. In the *early* stages of silicosis the mediastinal shadow may be widened, owing to the enlargement of the tracheobronchial lymph nodes from accumulated dust and cellular reaction to it; later, when specific fibrosis develops, the tissues generally contract and the nodes decrease in size. The changes described under 2 and 3 may be caused by many forms of irritation; if they are due to silica they are identifiable only by microscopic examination. They do not apparently interfere with respiratory function, and they are not of diagnostic significance.

The asbestos industry has grown extensively in the past quarter of a century. This has caused attention to be centered around it as a factor in industrial disease. In this country, the reports of Lynch and Smith, Lanza *et al.*, Shull, Pendergrass, and others, and the experimental work of Gardner have emphasized the importance of this condition.

The process is confined to the lungs and pleura and if the disease becomes sufficiently advanced it will produce definite increase in the markings of the lungs and thickening of the pleura.

One cannot conclude a discussion of this kind without pointing with pride to the early work of many of our colleagues not only in roentgenology, but electrical engineers and physicists and to the fundamental contributions in anatomy, physiology, and pathology; all of which have provided for the roentgenologists information from which it has been possible to develop criteria that have become so essential in rendering a diagnosis in occupational lesions of the chest.

Whereas, in the early days roentgenography of the chest was utilized only occasionally, today modern preventive medicine cannot be practiced intelligently unless a roentgen examination is a part of the program. Finally, the need for chest surveys has become so great, a new procedure, photofluorography, has been developed and the work of F. J. Hodges, Morgan, and Hilleboe has been outstanding in this country.

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REFERENCES

1. Arrigoni, A. La pneumoconiosi da bario. *Clin. med. ital.*, 1933, *64*, 299–324.
2. Bianchi, G. La tubercolosi polmonare nei lavoratori del marmo. *Gazz. d. osp.*, 1928, *49*, 915, 948.
3. Bianchi, G. La pneumoconiosi nei lavoratori del marmo. Osservazioni cliniche e radiologiche. Richerche sperimentali. In: Studi sulla pneumoconiosi in Italia, 1930, pp. 27–78. Min. delle Corporazioni, Istit. Poligr. dello Stato, Rome. (Res. in Silicosis.)
4. Bianchi, G. Sulla pneumoconiosi nei lavoratori del marmo. *Med. del lavoro*, 1931, *22*, 425–431.
5. Béclère, A. Les rayons de röntgen et le diagnostic de la tuberculose. J. B. Baillère et fils, Paris, 1899.
6. Benedikt, M. Zur Tuberculosefrage. *Wien. med. Wchnschr.*, 1901, *51*, 1249–1251.
7. Boardman, W. W. Pneumonoconiosis. Am. J. Roentgenol., 1917, *4*, 292–299.
8. Bouchard, C. La pleurésie d'homme étudiée à l'aide des rayons de roentgen. *Gaz. d. hôp.*, 1896, p. 147.
9. Brown, Percy. Radiologic Diagnosis. In: The Science of Radiology. Otto Glasser, Editor. Charles C Thomas, Springfield, Ill., 1933, pp. 139–186.
10. Collis, E. L. Phthisis among flint knappers. Royal Commission on Metalliferous Mines and Quarries. 1914, Vol. 2, App. J., p. 32.
11. Crane, A. W. Skiascopy of respiratory organs. *Philadelphia Month. M. J.*, 1897, *1*, 154.
12. Davis, G. G., Salmonsen, E. M., and Earlywine, J. L. The Pneumonokonioses (Silicosis). Industrial Medicine, Inc., Chicago, 1934.
13. Drinker, P. Dust, fumes, and smoke. Internat. Labor Office, Occupation and Health, 1930, *1*, 603.
14. Entin, M. Ueber Pneumonokoniosen. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1915–1916, *23*, 19–30.
15. Gardner, L. U. Pathology and roentgenographic manifestations of pneumoconiosis. *J. Am. M. Ass.*, 1940, *114*, 535–545.
16. Harper, Archibald. Silicosis. *Colliery Guardian & J. Coal & Iron Trades*, 1934, *147*, 982–983.
17. Harrington, D., and Davenport, Sara J. Review of Literature on Effects of Breathing Dusts with Special Reference to Silicosis. Information Circular U. S. Bureau of Mines, March, 1935.
18. Hilleboe, H. E., and Morgan, R. H. Mass Radiography of the Chest. Year Book Publishers, Chicago, 1945.
19. Hodges, F. J. Photofluorography in chest survey projects. *Texas State J. Med.*, 1943, *39*, 19–23.
20. Hulst, H. Skiagraphy of the chest. *Tr. Am. Roentg. Ray Soc.*, 1904, pp. 89–94.
21. Ickert, F. Pneumoconiosis and tuberculosis. *Deutsche med. Wchnschr.*, 1924, *50*, 832–834.
22. Ickert, F. Lungenpigmentierungen und die Vorstellung der Anthrakose. (Zum Artikel von Jousset.) *Ztschr. f. Tuberk.*, 1929, *54*, 216–219.
23. Ickert, F. Ueber die Disposition zur Staublunge, zur Staublunge mit Tuberkulose und zur Staublungentuberkulose. *Ztschr. f. Tuberk.*, 1931, *60*, 134–143.

24. Ickert, F. Staublunge und Tuberkulose. (Uebersicht.) *Zentralbl. f. inn. Med.*, 1933, *54*, 609; 625.

25. Kassabian, M. K. Röntgen Rays and Electro-Therapeutics. J. B. Lippincott Co., Philadelphia, 1907.

26. Kranenburg, W. R. H. Silicosis in the Netherlands. Silicosis Rec. Internat. Conf., Johannesburg, Aug. 13–27, 1930. Internat. Labor Office, Ser. F, No. 13, pp. 339–368, 1930.

27. Lanza, A. J., and Childs, S. B. Roentgen Ray Findings in Miners' Consumption, Based upon a Study of 150 Cases. U. S. Health Bulletin No. 85, January, 1917.

28. Lanza, A. J., McConnell, W. J., and Fehnel, J. W. Effects of inhalation of asbestos dust on lungs of asbestos workers. *Pub. Health Rep.*, 1935, *50*, 1–12.

29. Levy-Dorn. Augnahmen mittels Röntgenstrahlen bei angehaltenen Atem. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1898–1899, *2*, 216–218.

30. Lynch, K. M., and Smith, W. A. Pulmonary asbestosis including report of a pure case. *Am. Rev. Tuberc.*, 1931, *23*, 643–660.

31. Merewether, E. R. A. Occurrence of pulmonary fibrosis and other pulmonary affections in asbestos workers. *J. Indust. Hyg.*, 1930, *12*, 198–222; 239–257.

32. Merewether, E. R. A. Memorandum on asbestosis. *Tubercle*, 1933, *15*, 109; 1934, *15*, 152.

33. Merewether, E. R. A., and Price, C. W. Reports on Effects of Asbestos Dust on the Lungs and Dust Suppression in the Asbestos Industry. H. M. Stationery Office, London, 1930.

34. Oddo, C. Anthracose pulmonaire et radiographie. *Marseille méd.*, 1899, *36*, 609–617.

35. Pancoast, H. K. Roentgenologic studies of pneumoconiosis and other fibrosing conditions of the lungs. *Ann. Clin. Med.*, 1923, *2*, 8–23.

36. Pancoast, H. K., Miller, T. G., and Landis, H. R. M. Roentgenologic study of the effects of dust inhalation upon the lungs. *Tr. Ass. Am. Phys.*, 1917, *32*, 97–108. Also Am. J. Roentgenol., 1918, *5*, 129–138.

37. Pancoast, H. K., Miller, T. G., and Landis, H. R. M. Roentgenological study of the effects of dust inhalation upon the lungs. University of Pennsylvania, 15th Rep. Henry Phipps Inst., 1921, *15–16*, 129–139.

38. Pancoast, H. K., and Pendergrass, E. P. Review of our present knowledge of pneumoconiosis; based upon roentgenologic studies, with notes on the pathology of the condition. Am. J. Roentgenol. & Rad. Therapy, 1925, *14*, 381–423.

39. Pancoast, H. K., and Pendergrass, E. P. Pneumoconiosis (Silicosis). A Roentgenological Study with Notes on Pathology. Paul B. Hoeber, New York, 1926.

40. Pancoast, H. K., and Pendergrass, E. P. A review of pneumoconiosis; further roentgenological and pathological studies. Am. J. Roentgenol. & Rad. Therapy, 1931, *26*, 556–614. Abs., *J. Indust. Hyg.*, 1932, *14*, 90.

41. Pancoast, H. K., and Pendergrass, E. P. Roentgenological aspects of pneumoconiosis and its medico-legal importance. *J. Indust. Hyg.*, 1933, *15*, 117–135.

42. Pancoast, H. K., and Pendergrass, E. P. Roentgenologic aspect of pneumonoconiosis and its differential diagnosis. *J. Am. M. Ass.*, 1933, *101*, 587–591.

43. Pancoast, H. K., and Pendergrass, E. P. Pneumoconiosis: importance of accuracy in roentgenological interpretation. *New England J. Med.*, 1933, *209*, 425–437.

44. Pancoast, H. K., Pendergrass, E. P., Riddell, A. R., Lanza, A. J., McConnell, W. J., Sayers, R. R., Sampson, H. L., and Gardner, L. U. Roentgenological appearances in silicosis and the underlying pathological lesions. *Pub. Health Rep.*, 1935, *50*, 989–996.

45. Payne, A. E., Pirow, Hans, and Roberts, F. G. Historical review of mining conditions on the Witwatersrand and the changes which have taken place since the early days of the fields. Silicosis Rec. Internat. Conf., Johannesburg, Aug. 13–27, 1930. Internat. Labor Office, Ser. F. N. 13, 1930.

46. Pendergrass, E. P. Pulmonary anatomy. Fourth Saranac Laboratory Symposium on Silicosis. 1939. 61–93. The occurrence of silicosis in a pure silica industry. Saranac Laboratory Symposium on Silicosis. 1939. 224–236.

47. Pendergrass, E. P. The roentgen diagnosis of silicosis and asbestosis. Chapter III. In: Silicosis and asbestosis. A. J. Lanza, Editor. Oxford University Press, New York, 1938.

48. Pendergrass, E. P. Some considerations concerning the roentgen diagnosis of pneumoconiosis and silicosis. Am. J. Roentgenol. & Rad. Therapy, 1942, *48*, 571–594.

49. Pendergrass, E. P., and Hodes, P. J. The healthy chest. Am. J. Roentgenol. & Rad. Therapy, 1937, *38*, 15–41.

50. Pendergrass, E. P., and Leopold, S. S. Benign pneumonoconiosis. *J. Am. M. Ass.*, March 24, 1945, *127*, 701–705.

51. Pusey, W. A., and Caldwell, E. W. The Practical Application of the Röntgen Rays in Therapeutics and Diagnosis. Second Edition. W. B. Saunders Co., Philadelphia, 1904.

52. Rieder, H., and Rosenthal, J. Röntgenuntersuchung der Lungen und der Bronchien. Lehrbuch der Röntgenkunde. J. A. Barth, Leipzig, 1913.
53. Sayers, R. R., and Lanza, A. J. In: Silicosis and Asbestosis. A. J. Lanza, Editor. Oxford University Press, New York, 1938, pp. 1–25.
54. Schürmann, W. Industrial dust; its control with special reference to legal measures. *Zentralbl. f. Gewerbehyg.*, Sept. 15, 1929, pp. 1–21.
55. Shull, J. R. Asbestosis; roentgenologic review of seventy-one cases. *Radiology*, 1936, *27*, 279–292.
56. Sparks, J. V. Pulmonary asbestosis. *Radiology*, 1931, *17*, 1249–1257.
57. Staub-Oetiker, H. Die Pneumokoniose der Metallschleifer. *Deutsches Arch. f. klin. Med.*, 1916, *119*, 469–481.
58. Steuart, W. Radiography in its relation to miners' phthisis on the Witwatersrand. *Arch. Radiol. & Electroth.*, 1923, *27*, 277–286.
59. Sternberg, M. Occupation and Health. Geneva, 1934, p. 455.
60. Thompson, W. G. The Occupational Diseases: Their Causation, Symptoms, Treatment, and Prevention. D. Appleton & Co., New York, 1914, p. 71.
61. Tyson, T. M., and Newcomet, W. S. Practical use of radiograph and fluoroscope in diseases of the lungs. *J. Am. M. Ass.*, 1900, *34*, 67–70.
62. Watkins-Pitchford, W. Diagnosis of silicosis. *Med. J. Australia*, 1923, *2*, 382–384.
63. Weinberger, M. Atlas der Radiographie der Brustorgane, E. M. Engel, Wien, 1901.
64. Williams, F. H. The Roentgen Rays in Medicine and Surgery as an Aid in Diagnosis and as a Therepeutic Agent. Macmillan Co., New York, 1901.
65. Williams, F. H. Röntgen rays in thoracic diseases. *Am. J. M. Sc.*, 1897, *114*, 665–687.
66. Wood, W. B., and Gloyne, S. R. Pulmonary asbestosis complicated by pulmonary tuberculosis. *Lancet*, 1931, *2*, 954–956.

FIFTY YEARS OF ROENTGEN RAYS IN GASTROENTEROLOGY

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A HALF century of medical progress, even in one branch of medicine, is a difficult subject for review in the brief space available in this special issue of our Journal. In the field of gastroenterology the onward march has been paced by the evolution of roentgenological advance in instruments and technique. The advance of our knowledge of the motor and many other physiological processes in the alimentary and biliary tracts has depended to a considerable degree on the aid of the roentgen rays in the physiological laboratory and in the clinic. From the diagnostic standpoint no examination of the digestive organs is now considered complete without the information supplied by a roentgenologic study. Many of the medical and surgical therapeutic procedures utilized are conducted under roentgen-ray guidance.

Gastroptosis was described as far back as 1750 by van Swieten and in 1770 by Morgagni. Cruveilhier in 1849 gave further attention to ptosis of the stomach, speaking of it as "vertical dislocation of the stomach." Bouchard placed great emphasis on ptosis of the digestive organs. Glénard[101] began in 1885 a series of communications in which he attempted to explain dyspeptic troubles by gastric and intestinal ptosis. It was perhaps unfortunate that at the time of the discovery of the roentgen rays, Glénard's disease, as it came to be called, occupied such an important place in medical practice, especially of those physicians giving special attention to the digestive organs, for one of the first and what was then considered most important uses to which the new rays were put in relation to internal medicine concerned the position of the stomach and colon.

The first record of an investigation of the gastrointestinal tract with the help of the roentgen rays is found in an article by Strauss[212] (1896) who wrote of fluoroscopic observations on the stomach by using gelatin capsules, the kind used for the administration of castor oil, filled with reduced iron oxide and bismuth subnitrate. The shadows were only very indefinite and the investigations were discontinued. Hemmeter[117] (1896) suggested the use of a solution of plumbic acetate in a gutta percha bag which could be swallowed and later withdrawn.

In 1897 a number of investigators employed the roentgen rays for observing the digestive tube. Walsh[218] recorded observations on the upper contour of the liver in a case of hydatid disease, mentioned the possibility of seeing the lower border of the stomach faintly outlined with gas, and described his study of a patient with intestinal obstruction who for a fortnight before the observation had taken 15 grains of bismuth three times a day. Benedict[20] tells of using gelatin capsules containing reduced iron, in February, 1897, for the study of the alimentary tract but failed because of inefficient roentgen-ray apparatus. However, on July 13, 1897, this method was successful in 3 cases.

Walter B. Cannon,[28] while still a medical student, undertook some work at the suggestion of Professor H. P. Bowditch, of Harvard University, who in the autumn of 1896 expressed the belief that the roentgen rays would give assistance in observing gastric motor activity. Cannon's very first experiments related to the movement of food in the esophagus, for which purpose the goose was selected. The head and neck were surrounded by a tall pasteboard collar which allowed free movement of the head without constriction of the neck (Cannon and Moser[29]). His first account of roent-

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genologic observations of the stomach of the cat was given at the meeting of the American Physiological Society in May, 1897, and later results in December of that same year.

Roux and Balthazard[189] (1897) should be credited with experiments on the stomach of frogs, dogs, and men, utilizing bismuth-filled capsules covered with celluloid to keep them from dissolving in the digestive tract.

Williams[227] employed the introduction of gas or air into the hollow organs, especially the colon. For the esophagus he utilized a spiral wire, as suggested by Lindermann in 1897, or a metallic sound or a soft rubber tube closed at its inner end and passed into the esophagus, then filled more or less with mercury or lead shot. Williams made his first experiments with a suspension of bismuth subnitrate in 1897, and suggested that if the examiner did not wish the bismuth to pass into the intestine he might wash it out of the stomach with a lavage tube. He gave credit to Cannon, whose early work was done on animals, for assisting him in some studies on children in September, 1899. There is no doubt that the credit for the introduction of the use of bismuth subnitrate mixed with food belongs to Cannon and to Williams, though probably there were others who made use of small doses of bismuth for similar purpose, especially for the study of the esophagus. An early advocate of bismuth in suspension for studying the stomach was Metcalf,[156] of Chicago.

Holzknecht[124] studied the esophagus with reference to stenosis in 1900.

However, the credit for the employment of bismuth salts in large doses, after proving that the ingestion of large doses is harmless, belongs to H. Rieder[184] (1904) of Munich. The Rieder meal was a standard for roentgenologic study of the digestive tube for many years and still is. Other outstanding pioneers in establishing standards for the roentgenologic study of the digestive tube were Pfahler,[171] the first of whose numerous publications on the subject appeared in 1905, Hulst,[127] Skinner,[198] and Crane[77] in America, and Holland,[119] Barclay,[9] and Hertz*[129] in England.

Aside from the investigation of the esophagus, the chief attention of roentgenologists was given, as above mentioned, to the location of the position of the abdominal viscera. Glénard's work[101] was so fresh in the minds of the medical profession that the new method was regarded as a God-sent aid in locating the lower border of the stomach and the position of the colon. Such added emphasis was placed on Glénard's teachings that for two decades gastroenteroptosis continued to occupy an important place in the description of roentgen findings of the gastrointestinal tract. It remained for Moody[163] (1929) to record his studies on 1,000 healthy university students, conducted over a period of ten years at the rate of 100 a year, which led him to recommend the abandonment of the term "ptosis" as applied to the digestive organs, and today few physicians explain a patient's digestive symptoms on the basis of "ptosis." Certain important data relative to the topography of the digestive tube were provided by studies of Holzknecht[124] (1906), Jollasse[133] (1907), Hertz[131] (1909), and Mills[158] (1917), among others, especially concerning the relation of the position of the digestive organs to body habitus.

It is impossible in this brief space to attempt a complete listing of all the contributors to the application of the roentgen rays to the study of the digestive tube; only the high lights will be given. Holzknecht[123] (1906) reported on gastric peristalsis and described the roentgen findings in cancer of the stomach. Reiche,[183] in 1909, reported on gastric ulcer craters. Ashbury,[6] at the 1910 meeting of the American Roentgen Ray Society, presented a paper on the recognition of gastric and duodenal ulcer by the detection of barium retained in the ulcer crater. At that time his work received little attention; yet today this find-

* Hertz later changed his name to Hurst and his later writings are under this name.

ing constitutes the basic roentgen evidence of gastroduodenal ulcer. In 1909 Kästle, Rieder and Rosenthal[136] reported on a sort of moving picture method which they called bioroentgenography. Haudek,[115] in 1910, published his epochal work on the diagnosis of gastric ulcer, especially of the body of the stomach, describing the niche which ever since has continued to be known by his name.

About this time barium sulfate replaced bismuth preparations as the generally used opaque medium for gastrointestinal work. Carman[31] laid much stress on roentgenoscopy confirmed by roentgenograms. Cole[67,68] and George and Gerber[91,92] placed emphasis on obtaining the greatest possible roentgenographic detail in the gastroduodenal region, employing the screen chiefly as a finder to make sure of proper positioning of the patient. Together these pioneers laid the foundation for the elaborate detail of the technique employed at present in gastric roentgenology. Haudek's double meal, described by Holzknecht[125] in 1911, is still in use in many clinics.

Cole,[67] George and Gerber[91] and Carman[31] all laid stress on the direct evidence of ulcer and carcinoma, as did Haudek,[115] whereas previously Haudek's teacher, Holzknecht,[125] had elaborated a number of indirect roentgen-ray signs of gastric disease. For instance, Holzknecht's symptom-complex No. 1: "(1) Bismuth residue after six hours; (2) normal stomach shadow on the screen; (3) achylia. Diagnosis: Small carcinoma of the pylorus." Holzknecht felt that a residue after six hours (with the bismuth-bread mixture) indubitably pointed to an organic obstruction of the pylorus. He argued that the cause must be either stenosis or spasm of the pylorus, and since spasm never occurs with achylia but, on the contrary, with hyperacidity, the diagnosis under the above complex must be a small carcinoma; and it should be operable, otherwise there would be some defect in the shape or extent of the bismuth shadow in the stomach. Another example: symptom-complex No. 4: "(1) Small residue after six hours; (2) sensitive pressure-point over the stomach; (3) normal gastric shadow. Diagnosis: Simple gastric ulcer." It was requisite that the sensitive point should be demonstrated roentgenoscopically as coinciding with the lesser curvature of the stomach where ulcer was frequently situated. Other roentgen signs of ulcer consisted of gastric antiperistalsis, displacement of the pylorus upward and to the left making a snail form of lesser curvature, and a stable or spastic intermittent transverse contraction of the stomach causing an organic or spastic hourglass formation.

But Holzknecht also recognized the importance of bringing out the detail of the gastric lesion by compression with a "distinctor" or wooden spoon[44] and with manipulation of the stomach under the screen with the hand protected by a lead rubber glove, a technique later emphasized by Carman in developing the "pad sign" in gastric ulcer. The American school laid great stress on the direct signs of gastroduodenal disease, later extending the same principles to the study of the bowel.

Holzknecht in 1909 was already practicing the method of "aimed" roentgenograms which some of us in this country have continued to use for more than thirty years. He considered it of the greatest advantage in the course of roentgenoscopy to place a roentgen plate behind the screen without altering in the slightest the relative position of the tube and the patient, and to expose it, with only a momentary interruption of his roentgenoscopic study. He considered that under many circumstances the roentgenoscopic examination was a preliminary to the roentgenography and that the screen acted as a finder for the roentgen tube. This Viennese practice was the forerunner of the so-called "spot film" method now so popular in the United States. Any size of film exposed in this manner is really a spot film, but because of the small size to which the film must be reduced before in most minds it is entitled to the term "spot film," it seems that these tiny films might better be called "dot films." At any rate, the evolu-

tion of apparatus which permits instantaneous recording of interesting phases of roentgenoscopic observations constitutes an important phase of advance in the roentgenologic study of the digestive tract.

Another important development was the idea of Baastrup[8] in 1924, founded on the elaborate studies of Forssell,[84] who devised a method of coating the walls of the stomach with bismuth and distending it with air. Forssell,[87] Åkerlund,[4,5] and Berg,[21,22] as well as Schwarz,[197] Ledoux-Lebard,[146] Barclay,[10] Weber,[222,224] Templeton,[215] and many others, have elaborated on the method of visualization of the gastrointestinal mucosa. No longer is there an effort to fill the stomach or bowel with a large opaque meal; now one seeks rather to visualize the mucosal pattern and to complete the study with a minimum of contrast material. Nor is the main effort carried out fluoroscopically in preference to the roentgenograms. The screen studies serve for observation of peristaltic activities and for gross details, but for the fine details which are needed for sure diagnosis, one must have recourse to roentgenograms, including the "spot films" made with compression when needed, the preliminary fluoroscopy serving more as an aiming device and for observation of mobility and peristalsis than for recognition of fine detail. Let anyone with sublime faith in the fluoroscope prepare his eyes ever so well and then try to make his final diagnosis on a cholecystography or an intravenous urography with the fluoroscopic screen alone! The ideal examination of the digestive tube today includes appropriate use, as needed in the individual case, of all the fluoroscopic and roentgenographic devices which the past experiences have taught us.

To enumerate in this brief space the various steps in the progress of gastrointestinal diagnosis generally and of the colon in particular and to name the various responsible authors without serious omissions would be almost impossible. A great many of the advances in gastrointestinal roentgenology were begun independently and simultaneously by two or more roentgenologists, often continents apart.

The early examinations of the colon were carried out by the introduction of air or gas to outline the sigmoid flexure and descending colon, not only for the determination of the position of the large bowel but also for discovering and identifying enlargements of neighboring organs, such as the kidneys, spleen or pancreas (Williams). Williams[227] also suggested that the large bowel might be injected with a fluid containing subnitrate of bismuth and its outline and position studied. He added that "we should remember that any liquid which is opaque to the rays must be heavy and that the risk of putting into the large intestine such a weight as might be dangerous to its integrity should not be taken."

Groedel discussed at some length the study of the large bowel by following through the opaque meal, and in 1909[110] he recommended the bismuth clysma. At about this time Haenisch,[112,113] of Hamburg, had progressed so far in his use of the contrast enema that he had developed the trochoscope, especially designed for the study of the large bowel by the aid of the opaque enema. The Haenisch trochoscope was the forerunner of most of the horizontal fluoroscopic devices developed in the United States during the next decade.

For several years the practice became general in colon studies to use a large opaque enema, injecting until the colon was completely filled and some of the opaque material had found its way into the small bowel. But the growing appreciation of visualization of the mucosal pattern of various organs, stimulated by the work of Forssell,[87,88] and others, led to the development of combining the simple opaque enema with the injection of air or gas. The leaders in Europe were Fischer,[82] Berg,[22] Schwarz,[196,197] and in the United States, Cole,[57] Weber,[224] Gershon-Cohen,[97,98] and many others.

Among the first after Pfahler to carry out roentgen examinations of the colon by the opaque clysma on a large series of pa-

tients was Case[41,46] who had completed five hundred such examinations by the end of the year 1911. From the first he learned to stress the need of interrupting the fluoroscopic examination at appropriate intervals to place a film upon the patient underneath the fluoroscpic screen, exposing it with the same tube with which the fluoroscopy was conducted. He emphasized the value of turning the patient under screen guidance so that oblique and even lateral films of the sigmoid could be made in this manner. This fluorographic technique, which he learned from Holzknecht, of Vienna, was believed to be the earliest American application of the so-called "spot films" in mass studies of the colon. He also emphasized the value of localized compression with the Holzknecht wooden "distinctor" during the exposure of the films.[44]

From this, together with the double-contrast technique of Fischer,[83] Berg,[22] Weber[224] and others, has been evolved with minor modifications the present-day method of roentgen examination of the colon. The patient is first studied with the opaque enema, the injection of which is watched under the fluoroscopic screen for every inch of its extent. So-called spot films are made, especially of the sigmoid, of the flexures, and of the cecum, turning the patient under screen guidance as much as necessary to throw into prominence the coil in question. The entire colon is then recorded on a 14 by 17 inch film, after which the patient is allowed to evacuate the opaque enema. Another roentgenogram then records the degree of emptying and permits study of the more or less collapsed colon, the more complete the emptying the better. This is often the most valuable part of the study and frequently enables one to state with finality that there are no polypi or other tumors in the colon. Should question remain or there be other indications, air is then injected but this is not done in all cases by any means. After the air has filled the colon and localized studies with compression have been terminated, stereoscopic roentgenograms of the double-contrast-enema-filled colon are then made. The work of Weber and of Gershon-Cohen is particularly deserving of special mention in connection with the double-contrast colon studies.

Of course, during and prior to the time that the opaque enema was being developed, the colon had been extensively studied by observing the intestinal transit of the opaque meal. Holzknecht in 1909 described "rush peristalsis" or "mass movements" occurring in the colon, later further studied by Barclay, Case, Jordan, and many others.

In the colon the early work related to morphology, physiology and ptosis, with now and then papers on carcinoma, such as by Pfahler[176] (1911) and Case[45,65] (1913). Then came a period in which emphasis was laid upon intestinal adhesions, either of congenital origin or acquired, and we learned of Lane's kink and Jackson's membrane, the latter emphasized by Skinner[199] in 1914 and by Cole[72] in 1921.

Béclère[17] (1909), Liertz[148] (1910), Belot[19] and Desternes[52] (1911), Case[40] (1912), George and Gerber[90] (1912), were among the early contributors to roentgenology of the appendix. Since that time numerous publications on the appendix have appeared.

Although I have not attempted to include complete consideration of the work of European colleagues, review of the progress in roentgenology of the colon would be decidedly inadequate were we not to mention the work of Hertz (Hurst) of England. His contributions dealt mostly with the cause and treatment of constipation. The publications of Schwarz, then of Vienna, were scarcely less important.

Early contributions to the roentgen findings in ulcerative colitis were made by Stierlin[208,209] and Kienböck.[138] American contributors were particularly Carman and Moore,[38] Weber and Bargen,[225] and Kirklin, cooperating with Bargen. The relation of colitis to polyposis was discussed by Bargen,[12] and the diagnosis of polyposis by

Weber,[222] and others. Ileitis (Crohn *et al.*[80]) which was at first thought to affect only the terminal ileum has come to be recognized as an ulcerative disease which may attack any part of the intestinal tract.

The wave of deep roentgen therapy in the treatment of pelvic carcinoma has brought in its wake numerous instances of post-irradiation ulcers and other damage of the sigmoid. This was first published as far back as 1920 but recently the lesion has again found a place in the literature.

Colonic diverticula were first described roentgenologically by Goldmann[105] (Freiburg) in 1907, who described a case showing multiple sacculations; then by Abbé[1] and LeWald, Case,[47,48] Carman,[30] George and Leonard,[95] and Spriggs and Marxer,[202] until it has become generally recognized as one of the commoner and most important lesions of the large intestine.

Amebic, actinomycotic, blastomycotic coccidioidal and other fungus infections, endometrial manifestations in the colon (Jenkinson and Brown[132]), various types of fistula connecting the colon with abdominal and pelvic viscera and with the skin, Hirschsprung's disease, nonspecific granuloma, lymphopathia venerea, internal herniations and volvulus are among other important lesions of the colon which in later years have drawn the attention of radiologists. Many of these abnormalities and lesions are found also in other parts of the digestive tract.

Spontaneous pneumoperitoneum as a method of detecting internal perforations of hollow viscera was described by Lenk[147] (1916), Dandy[81] (1919), Copher[74] (1924), Vaughan and Brams[217] (1925), Pendergrass and Kirk[169] (1929), to mention only a few of the contributors.

Artificial pneumoperitoneum had its period of prominence with Stein and Stewart[203] (1919), Orndoff[167] (1919), Sante[190,191] (1921) and others, finally a collective review by Case[54] (1921) which showed that there was an inescapable element of risk, even of death, and considerably diminished the popularity of the method. Nevertheless, as with most methods overemphasized at first, there have persisted a few valuable uses for pneumoperitoneum. In South America the method was used very extensively for the diagnosis of abdominal hydatid disease, but a leading radiologist of the Argentine remarked that if it were not for the prevalence of hydatid disease in certain parts of the Southern Continent and in Australia, there would have been no such extensive use of pneumoperitoneum.

The realization that half of the malignant neoplasms of the large bowel occur in the rectum and rectosigmoid where they can be easily recognized by proctoscopic examination has impelled many writers to urge that every patient for whom a roentgen study of the colon is needed should have a preliminary examination of the rectum, at least digitally and preferably by proctoscope. Such preliminary examination will surely determine the presence of some early lesions which would otherwise escape even a most painstaking roentgen study. Small colonic lesions which are easily discoverable during the first moments of visualization of the rectum with the contrast enema can be completely lost when the rectum becomes distended.[63] To overcome the handicap of such a failure to diagnose, Oppenheimer[166] has recently described a special technique for the double-contrast visualization of the rectal and rectosigmoidal mucosa.

Up to this point, our review has concerned lesions of the esophagus, stomach, duodenum, and colon. In the field of the small intestine, which for a long time has remained a field only slightly known to roentgenology, great progress has been made within the last decade. In the earlier years of the roentgen era the motor physiology of the small bowel was an important part of the early studies, especially by Cannon, who described its motor behavior in great detail, including segmentation movements which occurred with such rapid alterna-

tions of segmental contraction and relaxation as to suggest the keys of a piano being played by unseen hands.

Various authors had written on acute and chronic obstruction, but it remained for Mills[159] in 1921 at a meeting of the American Roentgen Ray Society to relate his extensive statistical studies on the small intestine. He lamented the scant effort which had been directed to roentgen study of the jejuno-ileum, and made a valuable record covering observations on the digestive tract of 6,000 persons. Mills conceived that organic small intestinal lesions, involving the wall, either primarily or secondarily, will modify the roentgen shadow of the contents of the loops involved and thus render direct diagnostic evidence of their presence. This testimony might not be as striking as in the case of the stomach and colon, nor as suggestive of the nature of the lesion. He observed that when there is organic obstruction of the alimentary tract there will be dilatation and motor delay proximal to the lesion, depending upon the degree of obstruction.

In his series of nearly 6,000 subjects, atypical small intestinal patterns due to organic conditions primarily involving the small intestine were found in 70 cases, 18 of them being due to carcinoma and 44 to peritonitis and adhesions other than those due to appendical disease, and 310 were cases where the small intestinal atypical forms were a secondary result of organic disease, such as lesions of the cecum and appendix or complication of appendectomy, and lesions of the colon, such as carcinoma, diverticulitis, extra-alimentary tract tumor pressure, hernia, and a few other lesions. He included a group of 156 cases which he considered were due to functional pathological states. Many of these would no doubt now be placed under the head of insufficiency states, avitaminosis, as conceived today.

Cole[69] in 1914 had reported on the small intestine in relation to the stomach and cap as observed roentgenologically. In 1926, with Morse,[164] he made extensive studies regarding the normal anatomy and especially the morphology of the small intestine, showing that the position of the jejuno-ileum varied but little in the prone and erect posture; and that the loops of small intestine were shown with much better detail and with only slight distortion with the patient in the prone position. They felt that the roentgenographic outline of the inner wall of the intestine, as shown by the barium, was an expression not only of the surface of the mucosa but also of the muscular coats. They quoted Mall who taught that in the embryo there are six primary coils of small intestine. These can usually be identified in the adult. Loop one forms the duodenum; the second, third, fourth, fifth, and sixth loops or coils constitute the jejunum and ileum, otherwise referred to as the mesenteric small intestine. Other valuable contributors to the basic understanding of roentgenology of the normal and pathological small bowel were Soper,[200] Ritvo,[187] Menville and Ané,[155] and Bouslog,[25,26] to mention only a few of the many authors.

Schwarz[194] (1911) was one of the earliest to describe chronic obstruction of the small bowel, demonstrating dilatation of the small intestinal loops approaching the colon in size, exaggerated visibility of the circular folds of the intestine, fluid levels surmounted by gas in the dilated small intestine when the patient was examined in the erect position, and slowing of the intestinal transit.

These findings were corroborated in 1913 by Stierlin.[211] In 1914 Case[50,56,59,64] emphasized that it was possible to detect the presence of acute obstruction of the small bowel roentgenologically without the administration of an opaque medium given by mouth. This author repeatedly urged the feasibility of taking the roentgen examination to the patient with bedside roentgen-ray equipment, emphasizing that it caused the patient no more disturbance to slip a film under him than to place him on a bedpan. Many others have written on

the subject of acute small intestinal obstruction, including Sante[192] (1935). Wangensteen[220,221] in 1937 discussed at great length the value of the roentgen method in collaboration with other methods, particularly emphasizing that the roentgen ray furnishes reliable information, which can be learned in no other way, concerning two important particulars: (1) The grade of intestinal distention and the location of the distended coils, and (2) whether free gas is present in the peritoneal cavity.

In the study of suspected acute small bowel obstruction, very early objection was raised to the employment of bismuth or barium for fear of hastening the development of a complete obstruction. Some surgeons even protested against the use of barium for the study of the colon by the retrograde method, fearing an impaction might bring on an acute obstruction, and they recommended the use of a solution of sodium iodide. Case, beginning in 1912, had used barium sulfate routinely to supplement survey roentgenograms of the abdomen in the study of suspected ileus but in later years to meet objections to the insoluble heavy salts he recognized the value of the aqueous solution of thorium dioxide (umbrathor) and has used it in place of barium sulfate for the study of suspected ileus for the last eighteen years. Umbrathor, being an aqueous solution of thorium dioxide, remains fluid and presents no possibility of impaction above a stricture.

The present-day recommended technique for the study of a case of suspected acute intestinal obstruction should include (1) survey roentgenograms of the abdomen, in the erect position if possible; if not, with the patient lying on the side as well as supine; (2) the immediate administration of umbrathor when one first suspects the obstruction so that in case of delay in reaching a decision more definite visualization will result when the harmless umbrathor finds its way down the bowel to the site of the obstruction; (3) intubation if the attending physician dares to delay action for the use of the Miller-Abbott tube for decompression. Further studies may be made by introducing umbrathor through the tube into the intestine. One serious danger which always must be recognized when one employs intestinal intubation in the diagnosis or treatment of acute intestinal obstruction is that the obstruction may be mechanical and that delay in operation may result in fatal gangrene of the bowel.

Postoperative adhesions, intussusception and volvulus have been variously reported on, but gallstone ileus deserves special mention. Borman and Rigler[24] (1937) pointed out that gallstone ileus is suggested when in the presence of ileus one finds air in the biliary passages, the air having reached the biliary tract through the internal biliary fistula which gave passage to the gallstone when it found its way into the intestine.

Diverticula of the duodenum were first described roentgenologically by Case[52] and by Forssell and Key[89] in 1913. Jejunoileal diverticula were first reported as discovered in roentgen studies by Case,[53] who in 1920 summarized his work of ten years. Contemporary valuable contributions were made by Cole and others,[73] and Roberts[188] and later by Stetten.[201]

Tuberculosis of the small intestine was early studied by many, including Stierlin,[208,209] whose "vacant space" came to be known as Stierlin's sign but which later was shown to be present not only in tuberculosis of the ileocecal region but also in other ulcerative intestinal lesions. Carman[32,33] wrote several important papers on the subject. Other prominent contributors were Brown and Sampson,[27] Gershon-Cohen,[97,98] Sussman,[213] and Weber.[223]

Carcinoma of the small intestine was an occasional diagnosis from the time of the earliest employment of the contrast meal, and occasional attention has been given to tumors of the intestine, benign and malignant, by authors too numerous to mention. Within the last ten years renewed interest has been injected into the effort to make more definite the evidence of carcinoma

and other tumors of the small intestine by the employment of the intubation technique popularized by a series of studies by members of the staff of the Department of Radiology, University of Pennsylvania, and associates in other clinical departments including Abbott and Pendergrass,[2] Pendergrass *et al.*,[170] Miller and Abbott,[157] and possibly others. Many of these studies were based on intestinal intubation.

Crohn, Ginzburg and Oppenheimer[80] first described regional ileitis in 1932, concluding that it was a pathological and clinical entity. Homans and Hass[126] in 1933 took issue with this idea, however, and insisted that regional ileitis was a clinical and not a pathological entity. Numerous publications on this subject have appeared in the literature, including that by Kantor,[137] on the roentgen diagnosis. The original concept of Crohn with various modifications has been generally accepted.

The crowning contribution to roentgenology of the small intestine is the recent book by Golden[104] which summarizes the newer advances in roentgenology of the small bowel, and gives a very complete discussion of the roentgen evidences of disturbances of nutrition, allergic reactions, physiologic behavior of the jejuno-ileum in response to various foods and drugs, and an especially interesting analysis of the roentgen evidence in the so-called deficiency states. Golden summed up his own observations as well as those of Mackie, Miller and Rhoads,[150] Mackie and Pound,[151] Gershon-Cohen, Weber, and many others.

Prior to 1924 the study of the gallbladder was conducted by the use of simple roentgenograms and by studies in which the ordinary roentgenograms were supplemented by the injection of air or of opaque material into the stomach and duodenum and the colon. Carl Beck[13,14,15] (1898) was the first to publish roentgenograms of gallstones in the living, including 2 cases in a report before the New York County Medical Association in December, 1899. As McCoy[153] later pointed out, there is some doubt as to the correctness of his diagnosis in these first 2 cases, but Beck did a great service to roentgenology in insisting on a number of technical factors to be observed in the exposure of the plates and in their interpretation. He also published a case of transposition of the viscera with a gallstone on the left side. Occasional cases of roentgenological demonstration of gallstones were also published by Köhler[14] (1904), Holland,[120] Matthias and Fett[152] (1905), and in 1910 at the meeting of the American Roentgen Ray Society in Detroit, Pfahler,[173,174] Haenisch[173] and Cole[173] each contributed reports on 3 cases. Case[42,43] (1913) was the first to report the demonstration of gallstones in a considerable number of individuals, finding gallstones in 40 cases in a series of 1,000 routine gastrointestinal examinations and in 8 others. George and Gerber[93] (1914) considered that the roentgen findings in disease of the gallbladder were so common that they would in future include the gallbladder area in all gastrointestinal studies. Holland,[121] Pfahler,[177] and Cole[70,71] again wrote on the subject as did Case,[51] George,[94] Knox,[142] Groedel,[111] Palmer[168] and others. Haenisch[114] in 1924 published a monograph on the roentgenologic investigation of the liver, the gallbladder and gallstones, in which he said he was stimulated by the American literature to make an intensive study and to give to his German colleagues the assurance that the subject deserved more attention than they had previously given to it. Case[42] in 1913 had estimated that it was possible to show gallstones roentgenographically in about 40 per cent of the cases in which they were present, the percentage depending, of course, on the number containing lime salts in sufficient proportion to show on the roentgenograms. In 1923 Carman[34] reported from the Mayo Clinic on 226 cases in which gallstones were found at operation, and stated that 38.4 per cent were previously diagnosed by roentgen study (very close to the figure estimated by Case ten years before). Carman emphasized the already expressed general opinion that a negative report of

gallstones on the survey roentgenograms of this region was worthless.

A new era of gallbladder diagnosis dawned when Graham and Cole,[106,107,108] assisted by Copher and Moore, introduced a new method of gallbladder diagnosis utilizing the intravenous injection of tetrabromphenolphthalein. This method was developed after patient experimental work based on the evidence of Abel and Rowntree[3] that the phenolphthaleins as a class were largely excreted in the bile. Graham and his associates applied the name "cholecystography" to the visualization of the gallbladder with tetrabromphenolphthalein (later employing the sodium instead of the bromine salt), and the exposed roentgen films were called "cholecystograms."

Menees and Robinson[154] demonstrated the feasibility of the oral administration of the gallbladder dye. After a number of years of both intravenous and oral administration of the dye by various investigators, the idea of fractionating the gallbladder dye for oral use was the final advance needed for the oral method to almost completely supplant the intravenous administration of the phthalein compounds in gallbladder diagnosis.

On a series of more than 500 cases studied with intravenous cholecystography and later checked by surgery on the gallbladder, Case[61,62] was able to state that in 75 per cent of cases where the gallbladder failed to visualize ("absence of shadow") the probability of gallstones was 75 per cent; another 15 per cent were found to show gross gallbladder disease without stone, and 10 per cent of the cases showed extracholecystic biliary tract disease. The error on the series of 106 cases showing "absence of shadow" or failure to visualize was only 3 per cent; that is, only 3 cases were found at operation to be normal. His later experience with the divided oral doses gave equally accurate results. It followed from his statistical study (borne out by further check on operated cases) that if gallstones were shown by cholecystography, the diagnosis was almost certain; with failure of visualization there was 75 per cent chance of stones; if no gallstones were found in a gallbladder which was at all visualized, stones could be excluded with 95 per cent surety.

Other important contributions relative to cholecystography include that of Carman[35,36,37] and of Kirklin[139] and associates on cholecystography in general, and in particular that of Kirklin on tumors of the gallbladder,[140,141] Stewart and Ryan[206] on the advantages of division of the dose of the dye for cholecystography, Whitaker and Milliken[226] and Sosman *et al.*[201] on the influence of various foods on the emptying of the gallbladder after visualization with dye. Today cholecystography stands on a firm foundation as one of the most reliable tests of cholecystic disease and for estimating the motor function of the gallbladder. It is nowadays a rare event for a patient to be sent to surgery for the gallbladder in the face of normal cholecystographic findings.

Ever since the early days of roentgenology, especially since the work of Emil Beck[16] on the visualization of fistulous tracts with bismuth paste, biliary fistulae have been studied with the roentgen rays after the injection of some form of opaque material, but this type of examination was not systematically employed or productive of important diagnostic aid until Tenny and Patterson[216] injected bile ducts with bismuth paste and made observations on the flow of bile. Cotte[75,76] Walzell,[219] Ginzburg and Benjamin,[100] Judd and Phillips,[134] Kretchmar,[141] among others, introduced various opaque media, such as iodipin, umbrathor, thorotrast and hippuran and other preparations used for excretion urography, into biliary fistulae or through a T-tube. This method permitted not only the recognition of common duct stones but also common duct strictures, and assisted in the decision as to when the T-tube might be removed.

Mirizzi,[160,161,162] of Cordoba, Argentina, is credited with being the first (1932) to sug-

gest cholangiography during operation. Saralegui[193] (1935), of Buenos Aires, added much from his personal experience. Hicken Best and Hunt[118] made important contributions to the direct roentgen visualization of the biliary tree during operation to determine whether the ductal system is patent or obstructed, the position and number of calculi, the extent and location of stenotic lesions, the function of the sphincter of Oddi, also to outline communicating fistulae and to visualize dilatation and sacculation of the common duct. The injection of the biliary tract may be done immediately during the course of and as a part of the surgical procedure, or it may be done later through tubes left at operation or through fistula. Thorotrast is perhaps the best opaque medium for this purpose, though many have found lipiodine satisfactory. A contribution by Bettman, Tannenbaum and Arens[23] advocating immediate cholangiography in the operating room when there is the slightest suspicion that a stone may be present in the common duct has further stimulated interest in this valuable means of avoiding sins of omission in surgery of the biliary passages. Many hospitals are now equipped for the employment of cholangiography at the tableside in surgery of the biliary tract.

The study of the liver was begun very early in the roentgen era by the introduction of air or gas into the stomach and colon to estimate the size of the liver. Béclère[18] in 1911 described a method of orthodiagraphic examination of the liver, permitting the exact measurement of its diameters. As average figures for the normal, he gave the extreme transverse diameter of the liver as 28 cm., the anteroposterior 17 cm., and the vertical diameter as 8 cm. Pfahler[178] in 1926 also described the measurement of the liver by means of the roentgen ray in a contribution based on a study of 502 subjects. The behavior of the liver in cases of subphrenic and of intrahepatic abscess was carefully investigated and reported on by many writers. Hydatid cysts of the liver usually show some calcium in the walls of the cysts which permit their recognition.

Metastatic nodules of malignant disease in the liver were difficult of demonstration until the introduction of hepatolienography (hepatosplenography). The intravenous injection of thorotrast for visualization of the liver and spleen was introduced by Oka[165] and by Radt,[180] based on the tendency of this compound to be deposited in the reticulo-endothelial cells. The procedure was applied to the localization of tumors suspected of being located in the liver or spleen, to the diagnosis of cirrhosis of the liver and the recognition of abscesses, cysts, amyloidosis and other tumors, and particularly for the demonstration of metastatic invasion of the liver by malignant disease. Kadrnka,[135] Stewart, Einhorn and Illick[207] and Yater and Otell[228] made use of the method, the latter authors finding it very helpful. But serious theoretical objections to the use of thorotrast were made by a number of clinicians, and the Council on Pharmacy and Chemistry of the American Medical Association voted that thorotrast be not accepted for intravenous administration because of the very imperfect elimination of the thorium dioxide, its fairly high alpha-ray activity, and the possibility of further increase in its radioactivity by partial conversion to mesothorium and radiothorium. Because of these possible latent dangers, the method was not recommended and only lately has it begun to regain some of its former popularity. This has occurred in spite of the experimental work which indicated potential menace as reported by Taft,[214] on the one hand, though, on the other hand, clinicians have not reported any serious ill effects. Rigler, Koucky and Abraham[186] in 1935 reported on the effects of thorium dioxide sol on the human liver, following up 180 patients of whom 22 had had the solution injected one, two or three years before without any untoward results. Reeves and Apple[181] in 1933 had advised the use of thorium dioxide sol (thorotrast) in the diagnosis of liver abscess. Again in 1936, in reiterating the

value of thorotrast hepatosplenography in liver abscess, Reeves[182] stated that in an experience of seven years he had not observed any ill effects in any of his patients. Yater[229] and his colleagues in 1936, later in 1938, and finally Yater and Coe[230] in 1943, reporting on ten years' experience with hepatosplenography, were unable to find evidence that thorotrast has contributed to the death of any of 64 patients whose spleens and livers were studied with microscopic section after operation and death. Though 286 patients were followed over a period of more than ten years, no immediate or remote ill effects of importance were discovered. There was no evidence of latent radioactivity, depression of hepatic or splenic or hematopoietic function, lowered resistance to infection or development of malignant neoplasia at the site of injection. This method of hepatosplenography or hepatolienography continues to be of definite value in the diagnosis of cirrhosis of the liver, to determine the presence of metastases in the liver, and in the diagnosis of abscess of the liver. It seems that a concession may be made to the experimental results by reducing the amount of thorotrast injected, depending on improvements in roentgenographic technique to compensate for the diminished density of the hepatic shadows.

I am keenly aware of the sketchiness of the foregoing account of the evolution and present value of roentgenologic aid in the practice of gastroenterology. In spite of the fact that this review and its bibliography seem overly long, it is realized that many names of well known pioneers in American radiology whose work included contributions to gastroenterology have been omitted. This is much regretted. Apologies are extended to any who may feel that their work should have been mentioned. Much space could have been devoted to various gastroduodenal lesions and to anomalies, such as congenital shortening of the esophagus. European references have been given with no attempt to include all, even of the important contributors. Advances in the design and manufacture of roentgenologic equipment have added much to the onward march of the clinical use of the roentgen rays.

We dedicate our efforts to the future of gastrointestinal roentgenology with confidence that the emphasis will be placed on close cooperation between the radiologist and the referring physician.

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REFERENCES

1. Abbé, R. Case of sigmoid diverticulitis simulating malignancy; demonstrated by radiograph, operation and specimen. *Med. Rec.*, 1914, *86*, 190.
2. Abbott, W. O., and Pendergrass, E. P. Intubation studies of the human small intestine. V. The motor effects of single clinical doses of morphine sulphate in normal subjects. Am. J. Roentgenol. & Rad. Therapy, 1936, *35*, 289–299.
3. Abel, J. J., and Rowntree, L. G. On pharmacological action of some phthaleins and their derivatives, with especial reference to their behavior as purgatives, I. *J. Pharmacol. & Exper. Therap.*, 1909–1910, *1*, 231–264.
4. Akerlund, A. Roentgenologische Studien über den Bulbus duodeni, mit besonderer Berücksichtigung der Diagnostik des Ulcus duodeni. *Acta radiol.*, suppl. 1, 1921.
5. Åkerlund, A. Present-day criteria of x-ray diagnosis of duodenal ulcer. *Am. J. Surg.*, 1931, *11*, 233–259; 504–521.
6. Ashbury, H. E. X-ray findings in gastric and duodenal ulcer. Am. Quart. Roentgenol., 1911–1912, *3*, No. 3, 181–184.
7. Ashbury, H. E. Roentgenological aspect of intussusception. Am. J. Roentgenol. & Rad. Therapy, 1927, *18*, 536–545.
8. Baastrup, C. I. Roentgenological studies of inner surface of stomach and of movements of gastric contents. *Acta radiol.*, 1924, *3*, 180–204.
9. Barclay, A. E. Value of the x-ray in diseases of the digestive system. *Proc. Roy. Soc. Med.*, 1908–1909, 2, *Electro-Therap. Sect.*, 53–68.
10. Barclay, A. E. The Digestive Tract. Cambridge University Press, London, 1933.
11. Bargen, J. A., and Comfort, M. W. Association of chronic ulcerative colitis and multiple polyps. *Ann. Int. Med.*, 1930, *4*, 122–133.
12. Bargen, J. A., and Weber, H. M. Clinical and roentgenologic aspects of chronic ulcerative colitis. *Radiology*, 1931, *17*, 1153–1157.

13. Beck, C. On detection of calculi in liver and gall bladder. *New York M. J.*, 1900, *71*, 73–77.
14. Beck, C. Representation of biliary calculi by rontgen rays. *New York M. J.*, 1901, *73*, 446–448.
15. Beck, C. Cholelithiasis. *New York M. J.*, 1906, *84*, 469–479.
16. Beck, E. G. Bismuth paste in war surgery. Abs. in, Am. J. Roentgenol., 1919, *6*, 299.
17. Béclère. Présentation d'un radiogramme montrant sur le vivant l'image de l'appendice ileo-cecal. *Bull. et mém. Soc. de radiol. méd. de Paris*, 1909, *1*, 192–195.
18. Béclère, H. La röntgenographie du foie. Congrès de Dijon, 1911.
19. Belot, J. Radiographie d'appendice vu à l'examen radioscopique. *Bull. et mém. Soc. de radiol. méd. de Paris*, 1911, *3*, 326–328.
20. Benedict, A. L. Bismuth capsules; new application for the x-ray. *J. Am. M. Ass.*, 1898, *30*, 565.
21. Berg, H. H. Ueber das Verhalten des Schleimhautreliefs des Magens bei verscheidenen Erkrankungen. *Verhandl. d. deutsch. Gesellsch. f. inn. Med.*, 1926, p. 384.
22. Berg, H. H. Röntgenuntersuchungen am Innenrelief des Verdauungskanals. Georg Thieme, Leipzig, 1930.
23. Bettman, R. B., Tannenbaum, W. J., and Arens, R. A. Operative cholangiography. *Surgery*, 1943, *13*, 131–135.
24. Borman, C. N., and Rigler, L. G. Spontaneous internal biliary fistula and gallstone obstruction, with particular reference to roentgenologic diagnosis. *Surgery*, 1937, *1*, 349–378.
25. Bouslog, J. S., and others. Roentgenologic studies of infant's gastrointestinal tract. *J. Pediat.*, 1935, *6*, 234–248.
26. Bouslog, J. S. Normal stomach and small intestines in the infant. *Radiology*, 1942, *39*, 253–260.
27. Brown, L., and Sampson, H. L. Intestinal Tuberculosis. Its Importance, Diagnosis and Treatment. Lea & Febiger, Philadelphia, 1926.
28. Cannon, W. B. Movements of the stomach studied by means of the roentgen rays. *Am. J. Physiol.*, 1897, *1*, 359–382.
29. Cannon, W. B., and Moser, A. Movements of food in the esophagus. *Am. J. Physiol.*, 1897, *1*, 435–444.
30. Carman, R. D. Report of a case of diverticulitis of the sigmoid, with the roentgenologic findings. Am. J. Roentgenol., 1914–1915, *2*, 652–653.
31. Carman, R. D. Roentgenologic diagnosis of duodenal ulcer. Am. J. Roentgenol., 1916, *3*, 252–256.
32. Carman, R. D. The Roentgen Diagnosis of Diseases of the Alimentary Canal. W. B. Saunders Co., Philadelphia, 1917 and 1920.
33. Carman, R. D. Roentgenology of tuberculous enterocolitis. *J. Am. M. Ass.*, 1920, *74*, 1371.
34. Carman, R. D., MacCarty, W. C., and Camp, J. D. Roentgenologic diagnosis of cholecystic disease. *Radiology*, 1924, *2*, 80–89.
35. Carman, R. D., and Counseller, V. S. Roentgenologic diagnosis of cholecystic disease with aid of sodium salt of tetrabromphenolphthalein. Am. J. Roentgenol. & Rad. Therapy, 1924, *12*, 403–413.
36. Carman, R. D. Roentgenologic diagnosis of disease of gall bladder. *Radiology*, 1925, *5*, 101–103.
37. Carman, R. D. Cholecystography in its application to diagnosis of cholecystic disease. *Lancet*, 1925, *2*, 67–69. Also, *Minnesota Med.*, 1925, *8*, 707–712.
38. Carman, R. D., and Moore, A. B. Roentgenologic findings in ulcerative colitis. Am. J. Roentgenol. & Rad. Therapy, 1926, *16*, 17–20.
39. Case, J. T. Die Röntgenstereoskopie des Magens und des Darmes. *München. med. Wchnschr.*, 1912, *59*, 27–29.
40. Case, J. T. X-ray studies of ileocecal region and appendix. Am. Quart. Roentgenol., 1912–1913, *4*, No. 2, 77–95.
41. Case, J. T. X-ray observations on colonic peristalsis and anti-peristalsis. Tr. XVIIth Internat. Cong. Med., London, 1913, Section on Radiology; *Med. Rec.*, 1914, *85*, 415–427.
42. Case, J. T. Roentgenoscopy of liver and biliary passages with special reference to gall-stones. *J. Am. M. Ass.*, 1913, *61*, 920–925.
43. Case, J. T. X-ray examination of liver and gall-bladder. *Arch. Roentg. Ray*, 1913, *18*, 135–139.
44. Case, J. T. Word of caution concerning palpation under fluorescent screen. *Med. Rec.*, 1914, *85*, 1059–1061.
45. Case, J. T. Roentgenologic findings in malignant obstruction of the colon. *Journal-Clinic*, 1914, *111*, 216–219.
46. Case, J. T. Stereoroentgenography: The Alimentary Tract, 4 parts. Southworth Co., Troy, N. Y., 1914.
47. Case, J. T. Roentgen demonstration of multiple diverticula of the colon. Am. J. Roentgenol.. 1914–1915, *2*, 654–658.
48. Case, J. T. Multiple diverticula of the colon. American Atlas of Stereoroentgenology. Southworth Co., Troy, N. Y., 1916, Vol. 1, p. 20.
49. Case, J. T. Roentgen examination of the appendix. *New York M. J.*, 1914, *100*, 161–167.

50. Case, J. T. Roentgen studies after gastric and intestinal operations. *J. Am. M. Ass.*, 1915, *65*, 1628.
51. Case, J. T. Some statistics on the negative and positive roentgen diagnosis of gall-stones. Am. J. Roentgenol., 1916, *3*, 246–252.
52. Case, J. T. Roentgen observations on duodenum with special reference to lesions beyond the first portion. Am. J. Roentgenol., 1916, *3*, 314–326.
53. Case, J. T. Diverticula of small intestine, other than Meckel's diverticulum. *J. Am. M. Ass.*, 1920, *75*, 1463.
54. Case, J. T. Review of three years' work and articles on pneumoperitoneum. Am. J. Roentgenol., 1921, *8*, 714–721.
55. Case, J. T. Value of röntgen examination in early diagnosis of postoperative ileus. *Tr. West. Surg. Ass.*, 1922, p. 18. *Ann. Surg.*, 1924, *79*, 715–725.
56. Case, J. T. Value of bedside x-ray studies in immediate postoperative management of surgical cases. *Surg., Gynec. & Obst.*, 1923, *37*, 417–418.
57. Case, J. T. Jejuno-ileal diverticula. *Acta radiol.*, 1926, *6*, 230–240.
58. Case, J. T. Chronic obstruction of small intestine. *Radiology*, 1927, *9*, 1–14.
59. Case, J. T. Roentgenological aid in diagnosis of ileus. Am. J. Roentgenol. & Rad. Therapy, 1928, *19*, 413–425.
60. Case, J. T. Roentgen study of colonic diverticula. Am. J. Roentgenol. & Rad. Therapy, 1929, *21*, 207–220.
61. Case, J. T. Present status of roentgenological diagnosis of gall-stones. *Canad. M. Ass. J.*, 1929, *20*, 380–385.
62. Case, J. T. Interpretation of cholecystographic findings. *Ann. Surg.*, 1929, *89*, 222–236.
63. Case, J. T. Comparison of methods of roentgen examination of the colon. *J. Am. M. Ass.*, 1937, *108*, 2028–2032.
64. Case, J. T. Value of x-ray study in acute bowel obstruction. *Illinois M. J.*, 1938, *74*, 32[illegible]–330.
65. Case, J. T. A clinical approach to roentgen diagnosis of carcinoma of colon. *[illegible] M. J.*, 1941, [illegible], 145–152.
66. Cole, L. G. Radiographic study of motor phenomena of pyloric end of stomach and duodenum with a view to the early diagnosis of carcinoma, ulcer and adhesions [illegible] *Tr. Am. [illegible]*, 1912, [illegible]
67. Cole, L. G. [illegible]
68. Cole, L. G. Value of serial [illegible] in gastrointestinal diagnosis. *J. Am. M. Ass.*, 1912, *59*, 1947.
69. Cole, L. G. Relations of lesions of small intestine to disorders of stomach and [illegible] observed roentgenologically. *Am. J. M. Sc.*, 1914, *148*, 92–118.
70. Cole, L. G. Detection of pure cholesterin gall-stones by the roentgen rays. Am. J. Roentgenol., 1914–1915, *2*, [illegible].
71. Cole, L. G. Röntgenographic [illegible] of gall-stones and cholecystitis. *Surg., Gynec. & Obst.*, 1914, *18*, 218–227.
72. Cole, L. G. Veils in right hypochondrium and their differentiation from other [illegible] lesions and spasm. Am. J. Roentgenol., 1922, *9*, 137–148.
73. Cole, L. G., and others. Radiologic Exploration of the Mucosa of the Gastro-Intestinal Tract. Bruce Publishing Co., St. Paul, [illegible]
74. Cophe, G. H. Demonstration of spontaneous pneumoperitoneum by roentgen-ray; an aid in diagnosis of acute perforating peptic ulcer. *J. Am. M. Ass.*, 1924, *82*, [illegible].
75. Cotte, G. Sur l'exploration des voies biliaires au lipiodol en cas de fistule. *[illegible]*, 1926, *7*, 42–43.
76. Cotte, G. Sur l'exploration [illegible] des voies biliaires avec injection de lipiodol [illegible] cholécystostomie ou cholédochostomie. *Bull. et mém. Soc. nat. de chir.*, [illegible]
77. Crane, A. W. X-ray evidence in gastric ulcer. *Tr. Am. Roentg. Ray Soc.*, [illegible]
78. Crane, A. W. American [illegible] bismuth for examination of [illegible] stomach. Am. J. Roentgenol., [illegible] *2*, [illegible]
79. Crohn, B. B. [illegible] regional [illegible] *Am. J. Digest. Dis.* [illegible]
80. Crohn, B. B., Ginzburg, L., [illegible] G. D. [illegible] *J. Am. M. Ass.*, [illegible]
81. [illegible]
82. [illegible]
83. [illegible]

84. Forssell, G. Ueber die Beziehung der auf den Röntgenbildern hervortretenden Formen des menschlichen Magens zur Muskelarchitektur der Magenwand. *München. med. Wchnschr.*, 1912, *59*, 1588–1592. Also, Les rapports entre les formes radiologiques de l'estomac humain et l'architecture musculaire de la paroi stomacale. *Arch. d'électric med.*, 1912, *20*, 529–549.
85. Forssell, G. Ueber die Beziehung der Röntgenbilder des menschlichen Magens zu seinem anatomischen Bau. Gräfe und Sillem, Hamburg, 1913.
86. Forssell, G. Studies of the mechanism of movement of mucous membrane of the digestive tract. Am. J. Roentgenol. & Rad. Therapy, 1923, *10*, 87–104.
87. Forssell, G. Normale und pathologische Reliefbilder der Schleimhaut. Ein überblick über die autoplastik des Digestionskanals. *Verhandl. d. Gesellsch. f. Verd. u. Stoffwechselkrankh.*, 1927, 7 Tagung, 199–219.
88. Forssell. Beobachtungen über die Autoplastik des Digestionkanales. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1928, *37*, 393–394.
89. Forssell, G., and Key, E. Ein Divertikel der Pars descendens duodeni mittels Röntgenuntersuchung diagnostiziert und operativ entfernt. *Nord. med. Ark.*, 1915, *48*, No. 2, 48. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1916–1917, *24*, 48–57.
90. George, A. W., and Gerber, I. Value of the Röntgen method in study of chronic appendicitis and inflammatory conditions, both congenital and acquired, about the caecum and terminal ileum. *Surg., Gynec. & Obst.*, 1913, *17*, 418–427.
91. George, A. W., and Gerber, I. Positive diagnosis of duodenal ulcer by means of the roentgen-ray. Am. Quart. Roentgenol., 1912–1913, *4*, No. 4, 187–198.
92. George, A. W., and Gerber, I. Röntgen diagnosis of duodenal ulcer; comparison of direct and indirect methods. *Surg., Gynec. & Obst.*, 1914, *19*, 395–403.
93. George, A. W., and Gerber, I. Observations from study of a thousand gastro-intestinal cases. Am. J. Roentgenol., 1914–1915, *2*, 592–600.
94. George, A. W., and Leonard, R. D. Roentgen diagnosis of a pathological gallbladder. Am. J. Roentgenol., 1917, *4*, 321–336.
95. George, A. W., and Leonard, R. D. Value of the roentgen ray in the study of diverticulitis of the colon. The recognition of diverticulitis as a clinical entity; constipation as an etiological factor; pathological changes; symptoms; differential diagnosis; radiographic classification of multiple diverticula; bibliography. Am. J. Roentgenol., 1920, *7*, 421–431; 505–512.
96. George, A. W., and Leonard, R. D. The Pathological Gall-Bladder Roentgenologically Considered. Ann. Roentgenol., Vol. II. Paul B. Hoeber, Inc., New York, 1922.
97. Gershon-Cohen, J. Diagnosis of early ileocecal tuberculosis; preliminary report with special reference to double contrast enema. Am. J. Roentgenol. & Rad. Therapy, 1930, *24*, 367–388.
98. Gershon-Cohen, J. Ileocecal tuberculosis and the double contrast enema examination. Am. J. Roentgenol. & Rad. Therapy, 1933, *30*, 779–790.
99. Gershon-Cohen, J., and Shay, H. Barium enteroclysis; method for direct immediate examination of small intestine by single and double contrast techniques. Am. J. Roentgenol. & Rad. Therapy, 1939, *42*, 456–458.
100. Ginzburg, L., and Benjamin, E. W. Lipiodol studies of post-operative biliary fistulae. *Ann. Surg.*, 1930, *91*, 233–241.
101. Glénard, F. Application de la méthode naturelle à l'analyse de la dyspepsie nerveuse; détermination d'une espèce. *Lyon méd.*, 1885, *48*, 449–464; 492–505; 532–543; *49*, 8–28.
102. Golden, R. Observations on small intestinal physiology in presence of calcified mesenteric lymph nodes. Am. J. Roentgenol. & Rad. Therapy, 1936, *35*, 316–323.
103. Golden, R., Leigh, O. C., and Swenson, P. C. Roentgen-ray examination with the Miller-Abbott tube. *Radiology*, 1940, *35*, 521–533.
104. Golden, R. Radiologic Examination of the Small Intestine. J. B. Lippincott Co., Philadelphia, 1945.
105. Goldmann, E. E. Value of the x-ray in diagnosis of obscure abdominal disease. *Arch. Roentg. Ray*, 1908, *12*, 335.
106. Graham, E. A., and Cole, W. H. Roentgenologic examination of the gall-bladder, new method utilizing the intravenous injection of tetrabromphenolphthalein. *J. Am. M. Ass.*, 1924, *82*, 613–614.
107. Graham, E. A., Cole, W. H., and Copher, G. H. Visualizing of gallbladder by sodium salt of tetrabromphenolphthalein. *J. Am. M. Ass.*, 1924, *82*, 1777–1778.
108. Graham, E. A., Cole, W. H., Copher, G. H., and Moore, S. Diseases of the Gall Bladder and Bile Ducts. Lea & Febiger, Philadelphia, 1928.
109. Granet, E. Intestinal tuberculosis; clinical, roentgenological and pathological study of 2086 patients affected with pulmonary tuberculosis. *Am. J. Digest. Dis. & Nutrition*, 1935, *2*, 209–214.

110. Groedel, F. M. Grundriss und Atlas der Röntgendiagnostik in der inneren Medizin. J. F. Lehmann, München, 1909.

111. Groedel. Die Gallenblase im Röntgenbild. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1919–1921, *27*, 338.

112. Haenisch, G. F. Die Röntgenuntersuchung bei Verengungen des Dickdarms. *München. med. Wchnschr.*, 1911, *58*, 2375–2379.

113. Haenisch, G. F. Ueber direkte Irrigo-Radioskopie des Kolon. *Wien. klin. Wchnschr.*, 1913, *26*, 544.

114. Haenisch, G. F. Der Röntgenuntersuchung der Leber, der Gallenblase und der Gallensteine. J. A. Barth, Leipzig, 1924.

115. Haudek, M. Zur röntgenologischen Di gnose der Ulzerationen in der Pars media des Magens. *München. med. Wchnschr.*, 1910, *57*, 1587–1591.

116. Haudek, M. Die Röntgendiagnose des kallösen (penetrierenden) Magengeschwürs und ihre Bedeutung. *München. med. Wchnschr.*, 1910, *57*, 2463–2467.

117. Hemmeter, J. C. Photography of the human stomach by the Röntgen method; a suggestion. *Boston M. & S. J.*, 1896, *134*, 609–610.

118. Hicken, N. F., Best, R. R., and Hunt, H. B. Cholangiography; visualization of gallbladder and bile ducts during and after operation. *Ann. Surg.*, 1936, *103*, 210–229.

119. Holland, C. T. Stricture of oesophagus (taken after the patient had swallowed two ounces of strong bismuth mixture). *Arch. Roentg. Ray*, 1904, *9*, No. 6, plate ccii, opposite p. 122.

120. Holland, C. T. A case of gallstones, with radiograph. *Arch. Roentg. Ray*, 1906, *10*, 242.

121. Holland, C. T. On gall-stones. *Liverpool. M.-Chir. J.*, 1914, *34*, 308–313.

122. Holzknecht, G. Zur Diagnose der Oesophagusstenose. *Deutsche med. Wchnschr.*, 1900, *26*, 573–576.

123. Holzknecht, G. Ueber die radiologische Untersuchung des Magens im allgemeinen und ihre Verwertung für die Diagnose des beginnenden Carcinomes im besonderen. *Berl. klin. Wchnschr.*, 1906, *43*, 127 [illegible].

124. Holzknecht, G. Der normale Magen nach Form, Lage und Grösse. *Mitt. a. d. Lab. f. radiol. Diagn. u. Therap. i. k. k. allg. Krankenh. in Wien*, [illegible]

125. Holzknecht, G. Roentgen diagnosis of the stomach. *Arch. Roentg. Ray*, [illegible], *16*, [illegible]

126. [illegible]

127. Hulst, H. Roentgenography in diseases of stomach and intestines. *Tr. Am. Roentg. Ray Soc.*, 1906, 40–50.

128. Hunt, H. B., Hicken, N. F., and Best, R. R. Exploration of biliary ducts by cholangiography during and following operation. *Am. J. Roentgenol. & Rad. Therapy*, 1937, *37*, 542–564.

129. Hertz, A. F., *et al.* The passage of food along the human alimentary canal. *Guy's Hosp. Rep.*, 1907, *61*, 389–427.

130. Hertz, A. F. Study of constipation by means of the x-rays. *Arch. Roentg. Ray*, 1908–1909, *13*, 3–10.

131. Hertz, A. F. Constipation and allied intestinal disorders. H. Frowde, London, 1909.

132. Jenkinson, E. L., and Brown, W. H. Endometriosis; study of 117 cases with special reference to constricting lesions of rectum and sigmoid colon. *J. Am. M. Ass.*, 1943, *122*, 349–354.

133. Jollasse. Ueber den derzeitigen Stand der Röntgendiagnostik bei Magen Darmkrankheiten. *München. med. Wchnschr.*, 1907, *54*, 1424–1427. Abs. in, *Arch. Roentg. Ray*, 1908, *13*, 31.

134. Judd, E. S., and Phillips, J. R. Patency of biliary ducts, determined by radiopaque oil injected through a T tube previously placed in the common bile duct for the purpose of prolonged drainage. *Surg., Gynec. & Obst.*, 1933, *57*, 668–671.

135. Kadrnka, S. Hepatolienographie. Röntgenologische Darstellung des Parenchyms der Milz und Leber durch ein neues in die Blutbahn eingebrachtes kolloidales Kontrastmittel (Thorotrast). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1931, [illegible]

136. Kästle, C., Rieder, H., and Rosenthal, J. Ueber kinematographisch aufgenommene Röntgenogramme (Bio-Röntgenographie) der inneren Organe des Menschen. *München. med. Wchnschr.*, [illegible]

137. Kantor, J. L. [illegible]

138. [illegible]

139. [illegible]

140. [illegible]

141. [illegible]

142. Knox, R. Examination of the liver, gall bladder and bile ducts. *Arch. Radiol. & Electroth.*, 1919, *24*, 37; 79; 119; 156.
143. Köhler, A. Quoted by Brailsford, J. F. The x-ray diagnosis of pathological conditions of gall-bladder. *Brit. J. Radiol.*. 1927, *32*, 41–61; 81–110.
144. Kretchmar, A. H. Postoperative visualization of biliary system with radiopaque oils. *Am. J. Surg.*, 1933, *21*, 383–389.
145. Ledoux-Lebard, R. Manuel de radiodiagnostic clinique. Masson et Cie, Paris, 1933.
146. Ledoux-Lebard, R., and Garcia-Calderon, J. Les techniques d'examen de la muqueuse du gros intestin. *J. de radiol. et d'électrol.*, 1933, *17*, 429–466.
147. Lenk, R. Röntgenbefunde bei frischen Bauchschüssen. *München. med. Wchnschr.*, 1916, pp. 1278–1279.
148. Liertz, R. Die radiographische Darstellung des Wurmfortsatzes; ein Beitrag zur Aetologie der Epityphlitis. *Deutsche med. Wchnschr.*, 1910, *36*, 1269–1270.
149. Lindermann, E. Demonstration von Röntgenbildern des normalen und erweiterten Magens. *Deutsche med. Wchnschr.*, 1897, *23*, 266–267.
150. Mackie, T. T., Miller, D. K., and Rhoads, C. P. Sprue; roentgenologic changes in small intestine. *Am. J. Trop. Med.*, 1935, *15*, 571–589.
151. Mackie, T. T., and Pound, R. E. Changes in gastro-intestinal tract in deficiency states, with special reference to small intestine: roentgenologic and clinical study of 40 cases. *J. Am. M. Ass.*, 1935, *104*, 613–618.
152. Matthias, F., and Fett, E. Die Aussichten der Röntgenographie der Gallenkonkremente. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1906–1907, *10*, 199–207.
153. McCoy, C. C. Development of roentgenologic examination of biliary tract. *Radiology*, 1928, *11*, 13–26.
154. Menees, T. D., and Robinson, H. C. Oral administration of sodium tetraibromphenolphthalein; preliminary report. Am. J. Roentgenol. & Rad. Therapy, 1925, *13*, 368–369.
155. Menville, L. F., and Ané, J. N. X-ray study of passage of different foodstuffs through small intestine of man. *Radiology*, 1932, *18*, 783–786.
156. Metcalf, W. E. Original x-ray work and its value to stomach-diagnosis. *Philadelphia Med. J.*, August 26, 1899, pp. 401–402.
157. Miller, T. G., and Abbott, W. O. Intestinal intubation; practical technique. *Am. J. M. Sc.*, 1934, *187*, 595–599.
158. Mills, R. W. Relation of bodily habitus to visceral form, position, tonus and motility. Am. J. Roentgenol., 1917, *4*, 155–159.
159. Mills, R. W. X-ray evidence of abdominal small intestinal states embodying an hypothesis of transmission of gastro-intestinal tension. Am. J. Roentgenol., 1922, *9*, 199–225.
160. Mirizzi, P. L. Cholangiography during operations on biliary tract. *Bol. y trab. de la Soc. de cir. de Buenos Aires*, 1932, *16*, 1133–1161.
161. Mirizzi, P. L. Diagnostic des obstructions incomplètes non calculeuses du cholédoque. *Presse méd.*, 1936, *44*, 150–154.
162. Mirizzi, P. L. Fisiopatologia del hepato-colédoco: Colangiografía operatoria. Libreria "El Ateneo," Buenos Aires, 1939.
163. Moody, R. O. Are diagnoses of enteroptosis, gastroptosis and coloptosis now justifiable? *Am. J. Surg.*, 1929, *7*, 470–473.
164. Morse, R. W., and Cole, L. G. Anatomy of normal small intestine as observed roentgenographically. *Radiology*, 1927, *8*. 149–153.
165. Oka, M. Eine neue Methode zur röntgenologischen Darstellung der Milz (Lienographie). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1929, *40*, 497–501.
166. Oppenheimer, A. Roentgen diagnosis of incipient cancer of the rectum. Am. J. Roentgenol. & Rad. Therapy, 1944, *52*, 637–646.
167. Orndoff, B. H. Pneumoperitoneum in x-ray diagnosis. Abs. in, Am. J. Roentgenol., 1920, *7*, 173.
168. Palmer, D. Advances made in roentgen-ray study of gall-bladder disease. Am. J. Roentgenol. & Rad. Therapy, 1923, *10*, 901–903.
169. Pendergrass, E. P., and Kirk, E. Significance of gas under the right dome of the diaphragm, with discussion of hepatoptosis. Am. J. Roentgenol. & Rad. Therapy, 1929, *22*, 238–246.
170. Pendergrass, E. P., Ravdin, I. S., Johnston, C. G., and Hodes, P. J. Studies of the small intestine. II. Effect of foods and various pathologic states on the gastric emptying and the small intestinal pattern. *Radiology*, 1936, *26*, 651–662.
171. Pfahler, G. E. Diagnosis of size, form, position and motility of the stomach and bowel by means of the x-ray. *Tr. College of Physicians*, 1905, *27*, 79–83. Also, *Arch. Physiol. Therap.*, 1905, *2*, 6–9.
172. Pfahler, G. E. Physiologic and clinical observations on the alimentary canal by means of the roentgen rays. *J. Am. M. Ass.*, 1907, *49*, 2069–2077.

173. PFAHLER, G. E. Detection of gallstones by Röntgen rays. AM. QUART. ROENTGENOL., 1911–1912, *3*, No. 1, 23–33.
174. PFAHLER, G. E. Roentgen rays in diagnosis of gall-stones and cholecystitis. *J. Am. M. Ass.*, 1914, *62*, 1304–1307.
175. PFAHLER, G. E. Gastric and duodenal adhesions in gall-bladder region, and their diagnosis by the roentgen rays. *J. Am. M. Ass.*, 1911, *56*, 1777–1779.
176. PFAHLER. Roentgen ray diagnosis of carcinoma of stomach and bowel. Abs. in, AM. QUART. ROENTGENOL., 1911–1912, *3*, No. 2, 153.
177. PFAHLER, G. E. An improvement in the technique of gall bladder diagnosis. AM. J. ROENTGENOL., 1914–1915, *2*, 774–775.
178. PFAHLER, G. E. Measurement of the liver by means of roentgen rays based upon a study of 502 subjects. AM. J. ROENTGENOL. & RAD. THERAPY, 1926, *16*, 558–564.
179. DE QUERVAIN, F. Zur Diagnose der erworbenen Dickdarmdivertikel und der Sigmoiditis diverticularis. *Deutsche Ztschr. f. Chir.*, 1914, *128*, 67–85.
180. RADT, P. Eine Methode zur röntgenologischen Kontrastdarstellung vom Milz und Leber. *Klin. Wchnschr.*, 1929, *8*, 2128–2129.
181. REEVES, R. J., and APPLE, E. D. Use of thorium dioxide in diagnosis of liver abscess. *J. Am. M. Ass.*, 1933, *100*, 1682–1683.
182. REEVES, R. J. Use of thorium dioxide in roentgenographic study of liver abscess. AM. J. ROENTGENOL. & RAD. THERAPY, 1936, *36*, 923–927.
183. REICHE, F. Zur Diagnose des Ulcus ventriculi im Röntgenbild. *Forstchr. a. d. Geb. d. Röntgenstrahlen*, 1909–1910, *14*, 171–173.
184. RIEDER, H. Beiträge zur Topographie des Magen-Darmkanales beim lebenden Menschen nebst Untersuchungen über den zeitlichen Ablauf der Verdauung. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1904–1905, *8*, 141–172.
185. RIEDER. X-ray examination of internal organs. Abs. in, *Arch. Roentg. Ray*, 1906–1907, *11*, 58.
186. RIGLER, L. G., KOUCKY, R. F., and ABRAHAM, A. L. Effects of thorium dioxide sol (thorotrast) on human liver. *Radiology*, 1935, *25*, 521–532.
187. RITVO, M. Roentgen diagnosis of lesions of jejunum and ileum. AM. J. ROENTGENOL. & RAD. THERAPY, 1930, *23*, 160–169.
188. ROBERTS, D. Recognition and treatment of intestinal diverticula. *Surg., Gynec. & Obst.*, 1918, *26*, 211.
189. ROUX, J.-C., and BALTHAZARD. Zur l'emploi des rayons Röntgen pour l'étude de la motricité stomacale. *Compt. rend. Soc. de biol.*, 1897, *49*, 567–569. Also, Roux, J.-C., and Balthazard, V. Étude du fonctionnement moteur de l'estomac à l'aide des rayons de Röntgen. *Arch. de physiol. norm. et path.*, 1898, *10*, 85–94.
190. SANTE, L. R. Detection of retroperitoneal masses by aid of pneumoperitoneum. AM. J. ROENTGENOL., 1921, *8*, 129–138.
191. SANTE, L. R. Conclusions drawn from consideration of 80 cases of pneumoperitoneum. *J. Radiol.*, 1921, *2*, No. 2, 9.
192. SANTE, L. R. Intestinal obstruction. AM. J. ROENTGENOL. & RAD. THERAPY, 1935, *34*, 744–754.
193. SARALEGUI, J. A. Las colangiografías en el estudio de la afecciones biliares. *Prensa méd. argent.*, 1935, *22*, 2199–2207. Also, Die Cholangiographien beim Studium der Gallenleiden. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *52*, 571–579.
194. SCHWARZ, G. Die Erkennung der tieferen Dünndarmstenose mittels des Röntgenverfahrens. *Wien. klin. Wchnschr.*, 1911, *24*, 1386–1390.
195. SCHWARZ, G. Ueber hypokinetische und dyskinetische Formen der Obstipation. *München. med. Wchnschr.*, 1912, No. 40.
196. SCHWARZ, G. Klinische Röntgendiagnostik des Dickdarmes. J. Springer, Berlin, 1914.
197. SCHWARZ, G., GOLDBERGER, J., and CROCKER, C. Diagnosis and Non-Operative Treatment of Diseases of the Colon and Rectum. P. B. Hoeber, Inc., New York, 1937.
198. SKINNER, E. H. Fluoroscopy of gastro-intestinal tract. AM. QUART. ROENTGENOL., 1911–1912, *3*, No. 3, 161–174.
199. SKINNER, E. H. Interpretation of pericolic membranes. AM. J. ROENTGENOL., 1913–1914, *1*, 474–480.
200. SOPER, H. W. Roentgen-ray diagnosis of lesions of the small intestine. AM. J. ROENTGENOL. & RAD. THERAPY, 1929, *22*, 107–119.
201. SOSMAN, M. C., WHITAKER, L. R., and EDSON, P. J. Clinical and experimental cholecystography. AM. J. ROENTGENOL. & RAD. THERAPY, 1925, *14*, 495–503.
202. SPRIGGS, E. I., and MARXER, O. A. Intestinal diverticula. *Quart. J. Med.*, 1925, *19*, 1–34.
203. STEIN, A., and STEWART, W. H. Roentgen examination of the abdominal organs following oxygen inflation of the peritoneal cavity. *Ann. Surg.*, 1919, *70*, 95–100.
204. STETTEN, DE W. Multiple diverticula of upper ileum. *Ann. Surg.*, 1921, *73*, 241–244.
205. STEWART, W. H. Advanced roentgen technique in diagnosis of oesophageal lesions. AM. J. ROENTGENOL., 1913–1914, *1*, 464–470.
206. STEWART, W. H., and RYAN, E. J. Further advancement in technique and interpretation of cholecystography by oral method. *New York State J. Med.*, 1926, *26*, 819–821.

207. Stewart, W. H., Einhorn, M., and Illick, H. E. Hepatography and lienography following injection of thorium dioxide sol (thorotrast). Am. J. Roentgenol. & Rad. Therapy, 1932, *27*, 53–58.
208. Stierlin, E. Die Radiographie in der Diagnostik der Ileozoekaltuberkulose und anderer Krankheiten des Dickdarmes. *München. med. Wchnschr.*, 1911, *58*, 1231–1235.
209. Stierlin, E. Die radiographische Diagnostik der Ileocecaltuberculose und anderer ulcerativer und indurirender Dickdarmprocess. *Verhandl. d. deutsch. Gesellsch. f. Chir.*, 1911, *40*, 170–171.
210. Stierlin, E. Zur Röntgendiagnostik der colitis ulcerosa. *Ztschr. f. klin. Med.*, 1912, *75*, 486–493.
211. Stierlin, E. Zur Röntgendiagnostik der Dünndarmstenose und des Dünndarmileus. *Med. Klin.*, 1913, *9*, 983–986.
212. Strauss. Beitrag zur Wurdigung der Diagnostichen Bedeutung der Röntgendurchleuchtung. *Deutsche med. Wchnschr.*, 1896, *22*, 161–163.
213. Sussman, M. L. "Chronic hyperplastic tuberculosis of the colon;" a further note. Am. J. Roentgenol. & Rad. Therapy, 1931, *25*, 676.
214. Taft, R. B. Demonstration of gamma radiation from living patient following thorotrast injection. *Radiology*, 1937, *29*, 530–532.
215. Templeton, F. E. X-Ray Examination of the Stomach. University of Chicago Press, Chicago, 1944.
216. Tenney, C. F., and Patterson, S. H. Injection of bile ducts with bismuth paste and observations on flow of bile. *J. Am. M. Ass.*, 1922, *78*, 171–173.
217. Vaughan, R. T., and Brams, W. A. Roentgen ray in diagnosis of perforated peptic ulcer. *J. Am. M. Ass.*, 1925, *85*, 1876–1878.
218. Walsh, D. Röntgen rays in medical work. *Arch. Roentg. Ray*, 1897, *2*, 33.
219. Walzel, P. Ueber die radiologische Beurteilung postoperativer Gallenfisteln. *Beitr. z. klin. Chir.*, 1927, *139*, 155–161.
220. Wangensteen, O. H. The Therapeutic Problem in Bowel Obstruction. Charles C Thomas, Springfield, Ill., 1937.
221. Wangensteen, O. H., and Lynch, F. W. Evaluation of x-ray evidence as criteria of intestinal obstruction. *Proc. Soc. Exper. Biol. & Med.*, 1930, *27*, 674–676.
222. Weber, H. M. Roentgenologic demonstration tion of polypoid lesions and polyposis of large intestine. Am. J. Roentgenol. & Rad. Therapy, 1931, *25*, 577–589.
223. Weber, H. M. Roentgenologic identification of commonly encountered chronic ulcerative diseases of the colon. Am. J. Roentgenol. & Rad. Therapy, 1933, *30*, 488–496.
224. Weber, H. M. Roentgen diagnosis of diseases of the colon; evaluation of methods. Am. J. Roentgenol. & Rad. Therapy, 1934, *31*, 607–613.
225. Weber, H. M., and Bargen, J. A. Forms of ulcerative colitis. Am. J. Roentgenol. & Rad. Therapy, 1940, *43*, 809–818.
226. Whitaker, L. R., and Milliken, G. Comparison of sodium tetrabromphenolphthalein with sodium tetraiodophenolphthalein in gall-bladder radiography. *Surg., Gynec. & Obst.*, 1925, *40*, 17–23.
227. Williams, F. H. The Roentgen Rays in Medicine and Surgery as an Aid in Diagnosis and as a Therapeutic Agent. Macmillan Co., New York, 1901.
228. Yater, W. M., and Otell, L. S. Differential diagnosis of diseases of the liver and spleen by the aid of roentgenography after intravenous injection of thorotrast (thorium dioxide sol). Am. J. Roentgenol. & Rad. Therapy, 1933, *29*, 172–181.
229. Yater, W. M., Otell, L. S., and Hussey, H. H. Hepatosplenography with stabilized thorium dioxide sol; follow-up study of 200 patients examined over a period of five years. *Radiology*, 1936, *27*, 391–409.
230. Yater, W. M., and Coe, F. O. Ten years' experience with thorotrast hepatosplenography. *Ann. Int. Med.*, 1943, *18*, 350–366.

ROENTGEN DIAGNOSIS IN UROLOGIC DISORDERS

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THE discovery of the x-rays by Wilhelm Conrad Röntgen in 1895 probably contributed more to urology than to any other branch of medicine. Previous urologic diagnoses were founded on evaluation of urinalyses and palpable masses in the abdomen, often difficult or impossible to associate or dissociate with urinary tract lesions. This was particularly true of those of the kidney because of the wide variation in kidney position. Bladder stones could be identified only by sounds or stone searchers.

The difficulty in urologic diagnosis and the slow development of urology may be illustrated by the following facts:

Perhaps the earliest mention of urologic diagnosis is in Egyptian writings of 3000 to 1150 B.C. The instruments used were bronze and imported tin knives, catheters,

FIG. 1. Male, aged forty, complained of back pain and hematuria for seven weeks. Three years ago he passed calculi with hematuria. Roentgenogram of the kidney region showed no suggestive urinary tract shadows. A pyelogram revealed a rather large non-opaque stone in the left kidney pelvis. Cystoscopic examination showed blood coming from the left ureter. A large calculus was removed at operation. This case illustrates the importance of pyelography when calculi are suspected, even if the roentgenogram of the urinary tract is normal.

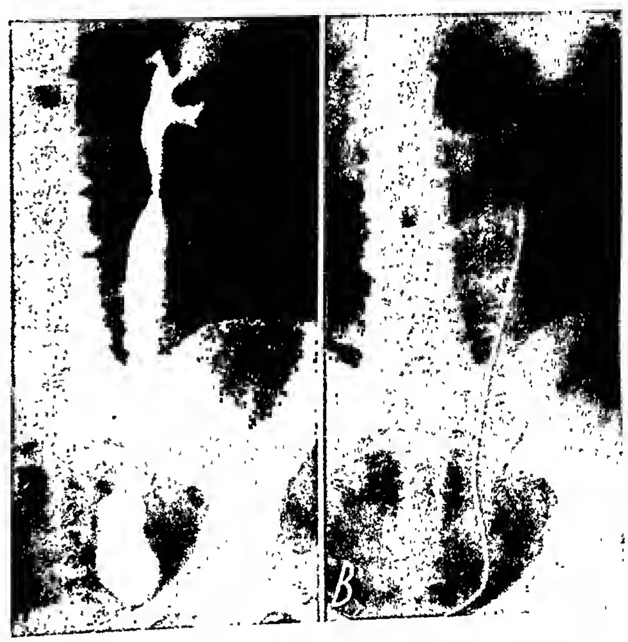
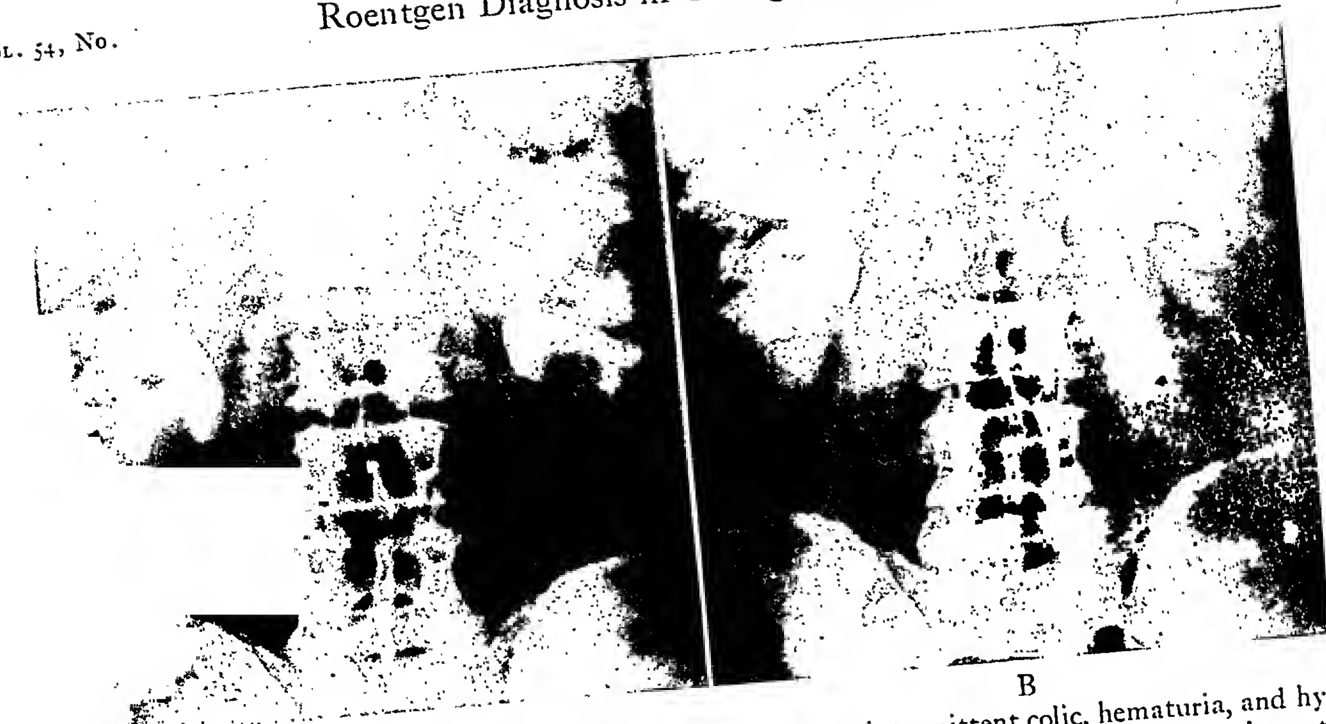


FIG. 2. Female, aged sixty, had frequency, pain, cystitis, and distress since 1910, when she was in bed for a month. Roentgenogram of the kidney region suggested a calcification in lower left ureteral area. Pyelogram showed large dilated left ureter (*A*). Kidney pelvis and calices appeared to be essentially normal. A large dense calcific deposit in the lower left ureter was believed to produce intermittent obstruction in the ureter and the patient's pain (*B*). Stone was not in contact with the catheter placed in the ureter so that it could be missed without a pyelogram. Previously, such a stone could not be palpated or felt by a catheter, particularly a wax-tipped catheter, or even by a sound. Now with opaque medium in the ureter, so-called ball-valve stones may be apprehended whether or not in contact with a catheter or other instrument introduced into the ureter. A left ureteronephrectomy eliminated the patient's symptoms.



A B

Fig. 3. Male, aged fifty-nine, had a left renal calculus for ten years, intermittent colic, hematuria, and hypertension. During the past year a calculus developed in the right kidney. Roentgenogram of the urinary tract showed a large staghorn calculus in each kidney (*A*). Urogram visualized both ureters with no obstruction or retention on either side (*B*). Bladder was normal and the renal function exceedingly good. The determination of function and dynamics of the ureter is of great importance in the treatment of calculi and is usually best done by excretory urography.

and sounds. Susruta, ancient Hindu medical authority, mentioned in 1000 B.C. various gold, iron, and wood tubes for urethral dilation. For centuries only such devices, particularly sounds, were available to men attempting to diagnose stones or strictures.

In his "Confessions" Jean Jacques Rousseau (1712–1778) described his personal experience with the diagnosis of calculi:

> Perceiving my suffering to be incessant, M. D. Luxembourg sent for Friar Come. The operation was cruel, indeed. Come thought he found a great stone. At the second examination he could not find it again. After a third examination with so much care and circumspection that I thought the time long, he declared there was no stone, but that the prostate gland was scirrhous and thickened. He added that I had a great deal to suffer and should live a long time.

Many centuries later men were still depending for location of a bladder stone upon the click of the calculus against a metal in-

no function on the right, a large infected left hydronephrosis probably due to tuberculosis, and apparent vesical tuberculosis.

Fig. 4. Female, aged thirty, complained of frequency. Bladder polyp was fulgurated seven weeks prior to examination. Fifteen years ago heminephrectomy was done for tuberculosis of the right kidney. Roentgen examination of the urinary tract showed extensive calcification, demonstrating tuberculosis of the right kidney with a closed ureter making an autonephrectomy. Right and left ureter also showed calcification. Excretory urogram revealed

Fig. 5. Female, aged twenty-nine, had hypertension with a systolic pressure of 200 mm. of mercury and a diastolic pressure of 122, for which she had every type of examination except investigation of urinary tract. Family history was negative. A left celiac ganglionectomy was done without beneficial result. Bilateral pyelograms showed a right duplex kidney, a left duplex kidney, two right ureters extending to the bladder, and the left ureter bifurcated about midway.

Pyelogram showed dilatation of the branch of the left ureter going to the upper calix which was somewhat blunted indicating partial obstruction at the point of bifurcation. This suggested a possible cause for the patient's hypertension. The lower half of the kidney was normal. The patient died from cerebral hemorrhage in about six months. Dr. Crile's comment was: "The rapid progress of this case showed that there was little hope for relief of hypertension by adrenal sympathectomy in a hypertension due to nephritis."

Fig. 6. Female, aged twenty-two, had contracted urinary bladder with symptoms since childhood. She had a cystoscopic examination, and Hunner ulcer was cauterized. Ureteral transplant was suggested. Both ureters were transplanted into the sigmoid. Urogram done before operation showed both kidneys to be normal. Excretory urogram done seventeen days after operation revealed a normal left kidney and ureter (*A*). From dilatation and hydronephrosis the right kidney was about twice the size of the left.

Excretory urogram a year later revealed normal kidneys with good function on both sides (*B*). This case illustrates the possibility of a temporary hydronephrosis after ureteral transplant and a return to normal after relief of temporary obstruction at the point of junction. Only by urography can such information be obtained.

strument, and until the advent of direct visualization, little was added during these centuries to methods of urologic diagnosis.

Then, early in 1896, the world was astounded at the announcement of the discovery of the x-rays by Wilhelm Conrad Röntgen, and the urologist acquired a new aid to urologic diagnosis. Development of this science, however, was severely handicapped by lack of progress in the manufacture of tubes and other equipment.

The urinary tract was first made visible or opaque to roentgen rays by Tuffier[12] in 1897. He introduced an opaque ureteral catheter into the urinary tract and then made a roentgenogram. Apparently, however, this method was not actually demonstrated until 1901, when Schmidt and Kolischer[9] published roentgenograms with catheters in the ureters. Later observers used bougies impregnated with metal.

Keyes,[5] writing in 1903, made the following comment:

Fig. 7. Female, aged twenty-five, complained of pain in the back for five years. At the time of pain patient had some fever and chills. She had no weight loss. A normal pregnancy two years prior to examination had been complicated only by chills. Pyelogram revealed a fused kidney with three separate divisions and bifurcation of the left half, which showed extensive hydronephrosis. Operation revealed a large globular mass (lemon-size) on the left. Turbid urine was expelled into the wound after the sac was excised. The sac was resected from the normal tissue of the left kidney, and the stump was ligated. The pyelogram made possible the diagnosis and elimination of the patient's symptoms.

Fig. 8. Female, aged forty-nine, complained of pruritus ani. A palpable mass, thought to be a kidney, was felt in the upper right portion of the abdomen. For years patient had frequency, occasional burning on urination, and some nocturia.

Urogram showed a large globular enlargement of the lower pole of the right kidney, compressing the lower portion of the kidney pelvis and displacing the ureter toward the midline. Upper calices appeared normal and showed prompt function. Operation was performed, and a large solitary cyst (orange-size) of the lower pole of the right kidney was resected. Ten years later the cyst had not recurred, and a well functioning kidney was present. Primary diagnosis was made by palpation of a mass and confirmed by a urogram.

Fig. 9. Female, aged twenty-one, complained of pain in the right side, inability to straighten right leg, weight loss, weakness, nocturia, and frequency. Temperature was 102.5° F. Duration of symptoms was six weeks. Twenty-four hours before examination symptoms became worse. Palpation suggested mass in right kidney region. Roentgenogram of the urinary tract showed a mass at lower pole of right kidney, left scoliosis, and loss of right psoas muscle border (*A*). Roentgenogram on deep breathing showed no movement of right kidney, whereas downward excursion of left kidney was normal.

Pyelogram showed normal left kidney. Right kidney was deformed by a mass extrinsic to the outer lower pole (*B*). These findings suggested perinephritic abscess. After drainage, injection of bismuth paste into the fistulous tract showed extension of the abscess through the retroperitoneal area (*C*). This was a tuberculous infection. Kidney excursion may be demonstrated by double exposure of a film of the urinary tract; one on inhalation and one on exhalation.

Fig. 10. Male, aged forty-nine, gave a history of acute colic and hematuria. A calculus was suspected in the left kidney. Pyelogram of the left kidney showed pronounced dilatation of the extreme lower minor calix with some indistinctness of the outline of the wall (*A*). Impression was early renal tuberculosis. Urinalysis showed no tubercle bacilli.

Eleven months later the patient complained of continued intermittent hematuria and pain in the left upper portion of the abdomen. Pyelogram showed normal right kidney, filling defect in the left kidney or absence of lower calix, and a narrowing at ureteropelvic junction (*B*). Impression was either tuberculosis or neoplasm in the lower calix. Nephrectomy showed papillary carcinoma of the lower pole of the left kidney.

The patient was seen two years later in good health. Roentgenograms of two recent cystoscopic examinations showed normal right kidney with a compensatory hypertrophy (*C*). There was no evidence of recurrence of another kidney lesion, or of metastasis. Patient had been free from urologic symptoms for thirteen years.

"Radiograph is useful in all cases and tells the surgeon where to look for calculi and relieves him of responsibility as to the presence of additional calculi in the ureter or kidney, which might be difficult to locate in the course of operation."

Fig. 11. Female, aged sixty-five, had pain in the upper portion of the abdomen. Clinical impression was questionable splenomegaly. Abdominal examination revealed large, freely movable, soft mass extending from upper left quadrant to umbilicus. There was tenderness over the mass. Urine was normal; leukocytes 7,800; hemoglobin 71 per cent; erythrocytes 4,110,000. Roentgenogram of the urinary tract revealed no suggestive urinary tract shadows. Right kidney was normal; left kidney was large.

Urogram showed prompt function of both kidneys. The right kidney appeared normal. There was no obstruction. A large tumor mass occupied the upper pole of the left kidney, which was displaced downward with marked compression of the pelvis. Total renal function was below normal. Impression was large hypernephroma of the left kidney. Survey for metastasis revealed none in the bones or chest. Roentgen therapy was given daily for one month, alternating anterior and posterior fields every other day. The patient died after six months.

This case illustrates the necessity of early diagnosis of kidney tumor, which is often first suggested by an abdominal mass, and which may be confirmed by urogram or pyelogram. In less than half the cases of hypernephroma does bleeding or other urinary symptoms appear until late in the disease. Excretory urography will often disclose such a lesion in an early state, thereby offering through surgery the only hope of cure.

Fig. 12. Female, aged thirty-six, had headaches and irregular menstrual periods. She had diabetes mellitus and hirsutism of upper lip, chin, cheek, and arms. Impression was hyperadrenalism and possible adrenal tumor. Routine roentgen examination did not show enlargement of adrenal glands or presence of tumor. Air injection revealed the kidneys and adrenal glands to be free from tumor and about normal in size.

Roentgen examination after the introduction of air perirenally made it possible to rule out the adrenals as a cause of symptoms. This illustration shows visualization of the right adrenal.

Next, an attempt was made to visualize the urinary tract by opaque media. Klose,[6] who had been using bismuth to visualize the gastrointestinal tract, introduced an emulsion of bismuth into the pelvis and ureter. The contrast, however, was not sufficient for diagnostic purposes. Not until 1906, about ten years after the discovery of the roentgen ray, was the urinary tract successfully visualized. Using a 5 per cent solution of colloidal silver, Voelcker and Lichtenberg[13] made the first satisfactory pyelogram.

They clearly demonstrated the value of

Fig. 13. Female, aged sixty-three, complained of attacks of pain in the lumbar region radiating to the lower abdomen, burning at the neck of the bladder, nocturia, and frequency. Previous cystoscopy showed a non-functioning left kidney and poorly functioning right kidney. Urinalysis was essentially normal. Cystoscopic examination showed trigonitis. A pyelogram showed multiple congenital ureteral cysts. A left nephrectomy was done, and the pathologic report revealed atrophy and fibrosis, hydronephrosis, some stenosis at the ureteropelvic junction, and multiple ureteral cysts. It would have been impossible to make this diagnosis without urography.

Fig. 14. Male, aged sixty, had occasional hematuria and weight loss of 25 pounds for one year. Six months prior to examination, clots obstructed the urethra. Cystoscopic examination was normal. Right ureter was catheterized with difficulty. By ureterogram a tumor of the ureter was located (*A*). The ureter and kidney were removed. *B* shows specimen, a primary carcinoma of the ureter.

Fig. 15. Male, aged thirteen. Diagnosis was left hydronephrosis due to aberrant vessel at lower pole (*A*). Roentgen examination, particularly an excretory urogram, made possible early detection. So often when this condition occurs on the right side, the patient is operated upon for appendicitis, gallbladder disease, or duodenal ulcer before a correct diagnosis is made. Or when it occurs on the left side, intestinal obstruction or another lesion is often first suspected before the kidney is examined.

The injected specimen illustrates the course of the aberrant vessel which produced the intermittent obstruction of the upper ureter with secondary hydronephrosis (*B*). In undiagnosed cases such a condition often results in complete destruction of the kidney before proper surgical treatment is instigated.

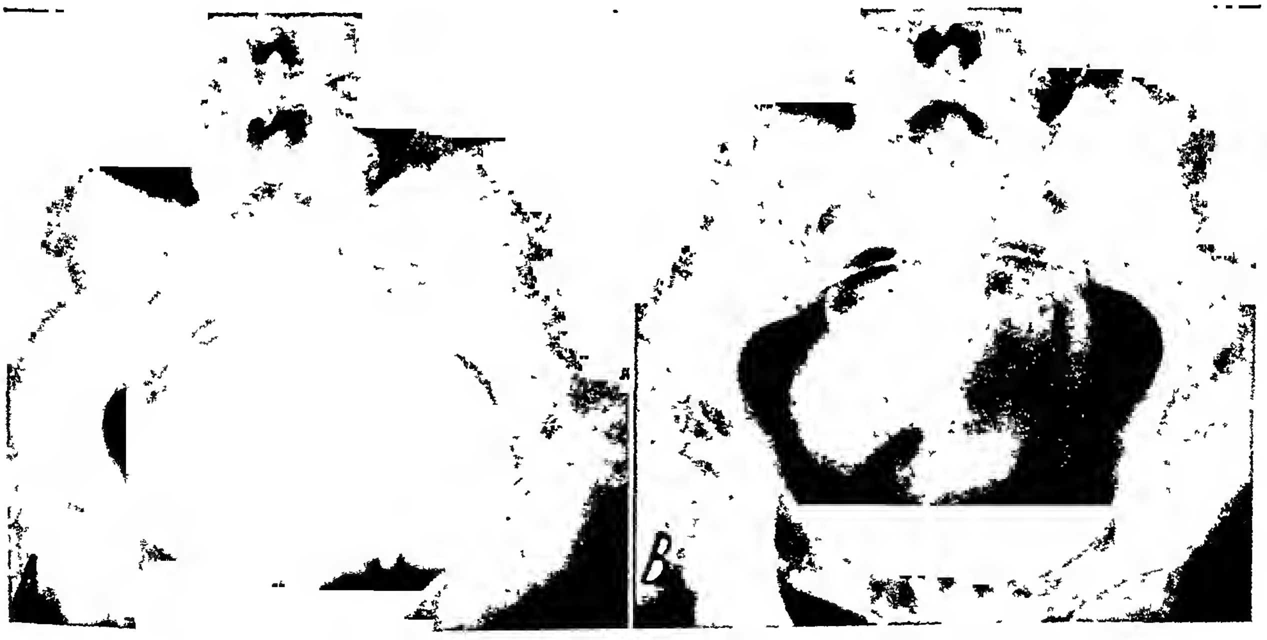


Fig. 16. Male, aged thirty-two, had frequency, burning on urination, and tenderness over the abdomen from symphysis to umbilicus. Prostate was indurated but of normal size. Cystogram showed large diverticulum in right anterior bladder quadrant with slight retention (*A*). The lower portion of the bladder was somewhat irregular. Urogram showed moderate hydronephrosis and dilatation of the lower left ureter (*B*). Impression was a large diverticulum of the bladder in the right upper quadrant and a bladder tumor. Total kidney function was good. Because the lesion was so extensive, a transurethral resection was done and radium implanted. Patient died three months after first examination of inoperable carcinoma of the bladder.

This case illustrates the possibility of overlooking even large bladder lesions if only a cystogram is made, particularly if no roentgenogram is made after emptying the bladder.

Fig. 17. Visualization of seminal vesicles is often of great diagnostic importance. The seminal vesicles are catheterized and an opaque medium injected into them. A seminal vesiculogram is illustrated in this figure.

A B

Fig. 18. In 1941 Trattner[11] made a preliminary report on the injection of the prostate gland with a partition catheter which makes possible visualization of the tubulo-alveolar units. The prostate gland on rare occasions had been visualized, particularly during a ureterogram, in patients who had abscesses from fistulous tracts or even a large anatomic orifice. Trattner's catheter with its two balloons, one for closure of the vesical neck and the other for blockage of the distal urethra, makes it possible to isolate the prostatic area from the rest of the urethra and from the bladder, and to introduce and retain fluid in the partitioned portion. By introduction of solutions into the tubulo-alveolar area of the prostate, roentgen visualization may be accomplished. The author uses diodrast solution of 50 to 75 per cent.

The following conditions may be determined by this method of examination: presence of a normal prostate, enlargement of the ducts, cavitation from abscess, presence of a cyst, obstruction of a duct by stone, prostatic hypertrophy with inflammation or interstitial fibrosis. In addition, a diverticulum or a fistula in the prostatic urethra may be visualized.

Excessive pressure during injection or an excessive amount of opaque medium may produce extravasation into the prostatic tissue and should be avoided. *A* shows a normal prostate, *B* shows abscess of the left side of the prostate.

This method of examining the prostate, one of the latest developments in urology, makes possible the diagnosis and treatment of certain pathologic conditions in the prostate gland (Fig. 18, *A* and *B*, courtesy of Trattner.[11])

pyelography in the diagnosis of hydronephrosis and suggested the possibility of its value in tumors. Many other observers followed with the diagnosis of numerous pathologic conditions in the urinary tract.

In 1911 Lichtenberg and Dietlen[7] reported a series of pyelograms after the introduction of oxygen into the urinary tract. Many attempts were made to obtain a satisfactory medium by improvement of silver salts. Notably, Braasch[3] in 1913 recommended that colloid silver crystals be pulverized, dissolved in lukewarm water, and carefully filtered.

Many attempts were also made to aid in filling of the ureters by changes in the patient's position, such as the erect and the moderate Trendelenburg position.

Braasch[2] in 1912 called attention to the value of pyelography in the diagnosis of renal tuberculosis and in the accurate location of many of the more important urinary tract lesions. He also contributed greatly to the interpretation of inflammatory changes in the kidney by the use of pyelography.

Some fatalities from pyelography were observed by various urologists and roentgenologists. The available media in the early days seemed to be the most important problem. Braasch[4] in 1915 in reporting 1,000 pyelograms made the following comment:

> Efforts should be made to discover a substance which will not injure the kidney, under any circumstances, and which may be safely employed in the hands of those with limited experience.

Bilateral pyelograms made with sodium iodide were often considered unsafe, but not until 1929 was this medium improved. Then Rowntree[8] and his co-workers demonstrated the possibility of excretory urography with the intravenous use of sodium iodide, although this medium was not sufficiently concentrated in the kidney for any practicable purpose. About this time, Binz[1] in Berlin was studying the selectan drugs. This came to the notice of Lichtenberg. He selected one preparation secreted by the kidney and with the aid of one of his associates, Swick,[10] accomplished an alternation in the No. 9 group of the drug selectan and found duroselectan to be of sufficient concentration and nontoxicity for practical use. Thus, uroselectan came into being. This was the beginning of intravenous urography.

In 1930 with Dr. William E. Lower I saw a demonstration by Swick of excretory urography in Dr. Leopold Jaches' laboratory in Mount Sinai Hospital, New York. Since that time, however, new combinations have become very satisfactory for excretory urography. By use of uroselectan many examinations are possible that could not previously be done by pyelography: the study of the urinary tract during pregnancy; the examination of the urinary tract in children, which may be accomplished by injecting the medium subcutaneously; the study of the kidneys and ureters in patients after transplantation of the ureters into the rectosigmoid; when prostate hypertrophy or lesions in the bladder preclude cystoscopy.

It is impossible in this contribution to refer to all of the urologists and roentgenologists, of whom there were many, whose untiring labors and contributions made possible the present status of roentgenology in urology.

In the accompanying illustrations and case histories are described a few practical applications of the roentgen ray in urology. These draw attention to the high tribute due Wilhelm Conrad Röntgen, who by his labors and perspicacity made urology one of the great specialties of medicine.

REFERENCES

1. Binz, A. The chemistry of uro-selectan. *Brit. J. Urol.*, 1930, *2*, 348–351. Also, *J. Urol.*, 1931, *25*, 297–309.
2. Braasch, W. F. Results of early diagnosis of urinary tuberculosis. *Interstate Med. J.*, 1912, *19*, 863–869.
3. Braasch, W. F. Recent progress in ureteropyelography. *J. Mich. M. Soc.*, 1913, *12*, 189–191.

4. Braasch, W. F. Pyelography (Pyelo-ureterography). W. B. Saunders Co., Philadelphia, 1915, pp. 31–32.
5. Keyes, E. L., Jr. Radiographic studies of renal pelvis and ureter. *Tr. Am. Urol. Ass.*, 1910, *3*, 351–367.
6. Klose, B. Radiographie eines durch das Kystoskop diagnostizierten Falles von kompletter Ureterenverdopplung. *Deutsche Ztschr. f. Chir.*, 1904, *72*, 613–617.
7. von Lichtenberg, A., and Dietlen, H. Die Darstellung des Nierenbeckens und Ureters im Röntgenbilde nach Sauerstofffüllung. Ein Beitrag zur Pyelographie. *München. med. Wchnschr.*, 1911, *58*, 1341–1342.
8. Osborne, E. D., Sutherland, C. D., Scholl, A. J., Jr., and Rowntree, L. G. Roentgenography of urinary tract during excretion of sodium iodid. *J. Am. M. Ass.*, 1923, *80*, 368–373.
9. Schmidt, L. E., and Kolischer, G. Radiographie an sonderierten Ureteren und Nieren. *Monatsb. f. Urol.*, 1901, *6*, 427–431.
10. Swick, M. Darstellung der Niere und Harnwege im Röntgenbild durch intravenöse Einbringung eines neuen Kontraststoffes, des Uroselectans. *Klin. Wchnschr.*, 1929, *8*, 2087–2089.
11. Trattner, H. R. Injection of parenchyma of prostate gland by use of partition catheter; preliminary report. *J. Urol.*, 1941, *46*, 283–285.
12. Tuffier, Th. Sonde ureterale opaque. Duplay et Reclus, 1897.
13. Voelcker, F., and Lichtenberg, A. Pyelographie (Röntgenographie des Nierenbeckens nach Kollargolfüllung). *München. med. Wchnschr.*, 1906, *53*, 105–107.

BACKGROUND AND BEGINNING OF CHOLECYSTOGRAPHY

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FOR almost thirty years the history of the roentgenology of the gallbladder was that of a constant purpose scantily fulfilled but tenaciously maintained in the face of difficulties. The record is marked by trial and error, by fresh hopes and new disappointments, by fruitless efforts and partial successes, all alternating with long periods of apparent stasis. Yet through all these years the real or fancied progress was sufficient to encourage persistence in the original design and inspire the renewed endeavor that led to an epochal advance. Indeed, it might reasonably be contended that the present highly developed art is wholly the product of the unswerving aim and persevering will of men. But whether it represents a purely human triumph, a natural outgrowth in the evolution of medicine or an inevitable resultant of fortuitous forces, physician and patient alike have reason to be glad that it exists.

When the roentgen rays were first presented to a marveling world late in 1895, the first thought was of their potential application to medicine, and this thought was further stimulated by Röntgen's depiction of his wife's hand. Roentgenographic revelation of bones was quickly followed by the demonstration of foreign bodies. Then concretions in the human body came into consideration. Gallstones that had been removed were subjected to roentgenography by various investigators and it was quickly learned that gallstones containing calcium cast appreciable shadows but that stones composed of cholesterol could scarcely be depicted. Early in 1897, little more than a year after Röntgen's discovery was announced, Buxbaum,[3] of Vienna, succeeded in securing shadows of gallstones in 4 of more than 30 patients examined. In 1900 an American, Beck,[2] was similarly successful in 2 cases. For more than a decade longer, roentgenologic examination of the gallbladder was confined to searching for shadows of gallstones. Apparatus was crude, gas tubes were fickle and demonstrations of the shadows were disappointingly rare.

Meantime, the examination of the alimentary canal with opaque media was developing rapidly, and in 1910 Schürmayer,[9] followed later by others, directed efforts toward the indirect diagnosis of cholecystic disease by disclosing signs of pericholecystic adhesions, such as fixation, displacement or deformity of the pyloric end of the stomach, the duodenum or the hepatic flexure of the colon. Other investigators pursued this method of approach and, although its results were not often fruitful, it served at least to stimulate interest in the entire problem. During the succeeding period came the development of the interrupterless transformer and of the Coolidge tube, inventions that facilitated all roentgenologic examinations, and study of the gallbladder received increasing attention. In 1917 George and Leonard[4] announced that in certain instances they had been able to produce and distinguish a shadow of the gallbladder when neither gallstones nor deposits of calcium were present. Further, they assumed, as a working hypothesis, that only when some pathologic change had taken place in the walls of the gallbladder or its contents would its shadow be depicted. To secure and discern the shadow, a scrupulous roentgenographic technique and careful scrutiny were requisite and only a few workers, who were willing to exercise such care, were rewarded with an increased efficiency in diagnosis.

Thereafter three bases for the diagnosis of cholecystic disease were available: name-

ly, shadows of gallstones, signs of pericholecystic adhesions and the shadow of the gallbladder. Each basis had constituted a step forward; yet after thirty years the goal desired had not been reached. Diagnosis still depended too largely on extraordinary skill, patience and courage and, although a few roentgenologists could point to a fairly high proportion of correct diagnoses, the roentgenologic method for the diagnosis of cholecystic disease was not generally held in high esteem. Nevertheless the medical profession will always be indebted to those men who fought a good fight and kept the faith. Among them, in addition to those already named, were Pfahler, Cole, Case and Manges in America; Knox and Holland in England; Béclère, Mauclaire and Infroit in France; Gottschalk, Haenisch, Witte, Matthias and Fett in Germany and Macleod, the Scot, in China. Besides these there were many others less conspicuous who aided in the common cause.

When the year 1922 was reached on the calendar, examination of the alimentary canal and the urinary tract with opaque media had attained a high degree of excellence and the possibility of extending this method to other hollow viscera was obvious. Rowntree and his associates[7] had shown that kidneys and renal pelves could be depicted roentgenographically after administration of sodium iodide in large doses. Abel and Rowntree[1] long before had determined that chlorinated phenolphthalein is excreted chiefly in the bile; Rous and McMaster[8] had proved that the gallbladder has the faculty of concentrating bile, and chemists had become proficient in forming new compounds by substitution. In retrospect, it is easy now to see that the stage was admirably set for the introduction of cholecystography but the full significance of these events and the logic of associating them together were not then readily apparent and the men of medicine, with one exception, continued merely to wish that a way of making the gallbladder plainly visible with the roentgen rays might be found. That exception was Evarts Ambrose Graham.

"One evening in the winter of 1922," said Graham,[5] "the idea occurred to me that since Abel and Rowntree had demonstrated the fact that the chlorinated phenolphthaleins are excreted almost entirely through the bile, it might be possible, by substituting for the chlorine atoms other atoms which would be opaque to the x-ray, to obtain a shadow of the gallbladder." After several months he obtained some of the free acid of tetraiodophenolphthalein. To render it more soluble it was converted into the sodium salt and in July, 1923, it was injected intravenously into six dogs by Graham's associate, Warren Cole.

In only one dog was a shadow of the gallbladder obtained and that shadow was faint. On inquiry it was learned that by an oversight this dog had been required to fast, while the other five had been fed as instructed. "From the standpoint of the future development of cholecystography," said Graham, "we often feel grateful to that one dog which cast a shadow, probably because he was accidentally given no food. If we had failed to get a shadow in all these animals, we probably would have abandoned the whole idea as a fruitless one. It is curious on how fragile a thread the destiny of some events hangs."

With hope thus revived, Graham continued his experiments and added Copher to the group conducting the investigation. Several animals died after injection of a moderate dose; only later was it learned that the deaths were probably due to impurities in the iodine compound. Meantime recourse was had to the sodium salt of tetrabromphenolphthalein. Excellent shadows of the gallbladder with less toxic effects from the drug were obtained in dogs. Finally a colored woman who presented a characteristic clinical picture of gallstones was given a carefully calculated dose of the bromine salt. To the consternation of the investigators, no shadow of the gallbladder appeared, although at operation many gallstones were found. Quickly, however, it occurred to the little group of workers that the reason for failure of the diseased gallbladder to produce a shadow was that the

organ could not properly concentrate the dye-laden bile. Accordingly the dye was given to a few persons whose gallbladders were supposed to be normal and good shadows were secured.

Thus it became clear that to obtain a distinct shadow the following conditions were necessary: "First, the material must get into the blood stream in sufficient amount. Second, it must be excreted by the liver into the bile in sufficient amount. Third, it must get into the gallbladder. Fourth, the gallbladder must be sufficiently normal to be able to concentrate its contents adequately by the absorption of water. If a single link in this chain of events were defective then either faint visualization or non-visualization would occur." On this rational basis the experiments proceeded with increasing success. The new method was demonstrated before the Congress of Internal Medicine at St. Louis in February, 1924, and a preliminary report by Graham and Cole was published in that month. Cholecystography was on its way.

In 1925 Whitaker and Milliken[10] concluded from experiments on animals that the sodium salt of tetraiodophenolphthalein was preferable to the bromine compound, for the iodine compound could be given in a smaller dose and with less hazard of any toxic effect. Shortly thereafter Menees and Robinson[6] found that either the bromine or the iodine combination could be given to patients orally instead of intravenously.

Roentgenologists everywhere then hastened to apply the test and, although much still remained to be learned, the immediate efficiency of the method was surprising. During its twenty years of existence, progress in cholecystography has been marked by experiments with different mediums, debate as to the relative efficiency of the oral and intravenous methods, investigations into the prevention and treatment of reactions from the drug, studies on the effects of food, drugs and intercurrent disease on the cholecystographic response, trials of various vehicles for oral administration, determination of the optimal time of oral administration in relation to the meal and the appropriate quantity and quality of the meal, application of the various fatty meals to induce emptying of the gallbladder at the proper stage of examination, experiments with administration through the duodenal tube and by enema, advances in roentgenographic technique and in the interpretation of cholecystograms and acceleration of research into the physiology of the gallbladder. Hundreds of informative contributions to the literature have been made. As a result of these and other accretions and adjustments, cholecystography today ranks high among major methods of examination and diagnosis and is justly esteemed to be an almost indispensable adjunct to clinical medicine.

REFERENCES

1. Abel, J. J., and Rowntree, L. G. On the pharmacological action of some phthaleins and their derivatives, with especial reference to their behavior as purgatives. *J. Pharmacol. & Exper. Therap.*, 1909, *1*, 231–264.
2. Beck, Carl. On the detection of calculi in the liver and gall bladder. *New York M. J.*, 1900, *71*, 73–77.
3. Buxbaum, A. Ueber die Photographie von Gallensteinen in vivo. *Wien. med. Presse*, 1898, *39*, 534–538.
4. George, A. W., and Leonard, R. D. The roentgen diagnosis of a pathological gallbladder. Am. J. Roentgenol., 1917, *4*, 321–335.
5. Graham, E. A. The story of the development of cholecystography. *Am. J. Surg.*, 1931, *12*, 330–335.
6. Menees, T. O., and Robinson, H. C. Oral administration of sodium tetrabromphenolphthalein—preliminary report. Am. J. Roentgenol. & Rad. Therapy, 1925, *13*, 368–369.
7. Osborne, E. D., Sutherland, C. G., Scholl, A. J., Jr., and Rowntree, L. G. Roentgenography of urinary tract during excretion of sodium iodid. *J. Am. M. Ass.*, 1923, *80*, 368–373.
8. Rous, Peyton, and McMaster, P. D. The concentrating activity of the gall bladder. *J. Exper. Med.*, 1921, *34*, 47–73.
9. Schürmayer, C. B. Pathologische Fixation bzw. Lageveränderung bei Abdominalorganen und die röntgenologische Diagnosestellung. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1910, *15*, 317–335.
10. Whitaker, L. R., and Milliken, Gibbs. A comparison of sodium tetrabromphenolphthalein with sodium tetraiodophenolphthalein in gall-bladder radiography. *Surg., Gynec. & Obst.*, 1925, *40*, 17–23.

THE DEVELOPMENT OF MODERN NEUROROENTGENOLOGY

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SINCE anatomical knowledge preceded roentgenography by centuries, the discovery of the latter required only a familiarization with the roentgenographic appearance of well known anatomical structures. This was particularly difficult, however, in the case of such a complicated region as the skull, and later on, when the techniques became available, of the brain. Progress at first was slow, hampered by crude machinery, bulky glass plates, slow and muddy photographic emulsions. Conversely, the development of roentgen apparatus up to the modern anode rotating tube, the application of stereoscopy to roentgenography, the introduction of films, Potter-Bucky diaphragm, intensifying screens and the application of contrast media to the study of the skull and its contents have led to such extensive development in this field of knowledge that one may be justified in applying to it the term *neuroroentgenology* and recognizing its exponents as *neuroroentgenologists.*

However, it would be short sighted, indeed, to credit this progress to mechanical developments alone, without taking into consideration the influence of demand arising from developments in other fields, such as neurological surgery, and above all the human spirit behind these mechanical developments, as well as the spirit that drives men to utilize them for man's needs as quickly as possible.

It is astonishing to find in the medical literature of 1900, 1901 and 1902, only five to seven years after Röntgen's discovery, papers, such, for example, as Benedikt's, devoted exclusively to the application of the roentgen ray to "diseases of the skull and brain." It is true that the eagerness of the early authors to use this great discovery as an aid in the diagnosis of *disease* led them, unfortunately, to fail to inform themselves adequately about the appearance of *normal* structures in the roentgenogram. Their efforts, however, stimulated others, and out of their crude beginnings, a modern science evolved which has become indispensable to neurological and neurosurgical diagnosis.

Refinements in technique and diagnosis began to multiply after World War I in response to demands made upon their roentgenologic colleagues by members of one of the newest specialties, namely, neurosurgery. Thus, familiar names of roentgenologists who are primarily concerned with craniocerebral diagnoses begin to appear in the 1920's and 1930's from centers of neurosurgery: Reynolds, Sosman, Pancoast, Pendergrass, Moore, Chamberlain, Camp, Dyke, Warren, Childes, Kornfeld and many of their pupils, and across the Atlantic, Schüller, Sgalitzer, Lysholm, Lindgren, Twining, and others.

The utilization of knowledge of normal anatomical appearances on the roentgenogram is particularly well illustrated by the recognition of the importance of the location of the pineal shadow. In 1918 Schüller, and in 1925, Naffziger called attention to the fact that the shift of this shadow away from its normal midline position in the anteroposterior or posteroanterior roengenogram of the skull usually indicates the presence of a mass on the side of the brain from which the pineal shadow has been displaced. This was followed by the studies of Vastine and Kinney (1927) and Dyke (1930), all pupils of Sosman, on the charting of the normal position of the shadow of the pineal gland as seen in the lateral roentgenogram of the skull, thus completing this most valuable indicator of the presence as well as lateralization and to some extent also of the localization of many brain tumors.

Other special studies of normal structures such as the optic foramina (Pfeiffer, Camp) and the petrous pyramids (Towne, Stenvers), while applicable to more limited

situations, were, nevertheless of great value in certain groups of cases.

With techniques thus well established and anatomical structures, in spite of wide variations, presenting familiar appearances, the field was open to discoveries of changes characteristic of certain pathological states as seen in the roentgenograms of the skull. In every branch of craniocerebral disease the contribution of roentgenography in diagnosis has become extremely valuable, whether it be in the recognition of congenital anomalies, the results of trauma, the changes associated with tumors, infections or nutritional diseases. It would be impossible, in this brief presentation, to mention all of the contributors to the progress in this field, and unfair to leave any of them out.

In the midst of all this activity, a new technique in roentgenography appeared which has already proved itself of greatest importance in neuroroentgenography and deserves special mention, namely, *planigraphy*. It would be repetitious, for readers of this Journal, for me to describe the principle and technique of this new development. The idea, in fact, was already patented, as long ago as 1922 by Bocage in France, but the credit for its development and application to clinical roentgenography belongs to a young Dutch scientist, Ziedses des Plantes. It is a matter of particular pride to neuroroentgenologists that Ziedses des Plantes is primarily a neuropsychiatrist, and while planigraphy is applicable to other parts of the body, his primary interest was to improve the roentgenologic technique in relation to the skull and its contents.

Ziedses des Plantes is also responsible for a less well known technique which he calls *subtraction*. This consists of making a preliminary roentgenogram of the skull, from which a diapositive is made, with the patient's head so fixed that the exact same position can be repeated later. This is accomplished by having the patient bite into a softened mass of dental wax that is fixed to a rigid frame. Later on, the hardened wax, which fits the patient's mouth exactly, forces the head into the original position. The second roentgenogram is made after gas has been injected into the ventricles. The original diapositive is now superimposed on the negative encephalogram. The positive of the first film blots out the negtive of the second film, leaving in sharp contrast the shadows not common to both films, namely, that of the gas-filled spaces. The same technique may of course be used before and after arteriography.

The principle of introducing a substance into the body which will cast a contrasting shadow on the roentgenogram and thus outline a hollow organ or a potential cavity was developed quite early in the history of roentgenography. As early as 1898 Cannon made use of it by introducing a bismuth mixture into the gastrointestinal tract, and in 1905 Robinsohn and Werndorff were already injecting pure oxygen into joint cavities, sinus tracts, tendon sheaths and tissue planes and obtaining roentgenograms of structures otherwise invisible. In 1913 Luckett published reproductions of ventriculograms occurring spontaneously in a patient who had sustained a fracture of the right frontal bone, as a result of which air was obviously insufflated into the ventricles through the fracture defect. The patient survived, so that air in the ventricles was obviously not fatal. But both the author of this paper and his readers failed to see the significance of this observation. It was not until 1918 that Dandy first introduced air intentionally into the human ventricular system. His first case was that of a child with hydrocephalus in whom he introduced the air directly by puncturing the ventricles through an open fontanelle. Dandy also devised the method of introducing air by means of lumbar puncture, and was the first to try other gases, such as oxygen, in place of air. This discovery was made use of by many workers and the application of it has resulted in a very large number of contributions to our understanding of the anatomy *in vivo* of the brain and of many of the diseases of the nervous system.

Other methods of roentgenologic study of the brain were being developed meanwhile. Thus in 1927 Egas Moniz introduced *cerebral arteriography*. His method consisted of exposing the common carotid ar-

tery surgically, and injecting a contrast medium—at first sodium iodide but later thorium dioxide—and taking successive roentgenograms of the skull to obtain a graphic representation of first the arterial, then the venous pattern of the side of the brain injected. In 1936 Loman and Myerson modified the procedure by devising a method of injecting the radiopaque material into the carotid artery by needle puncture through the intact skin without surgical exposure of the vessel. This method of examination is of particular value in the diagnosis of cerebral aneurysms, angiomas and other vascular tumors. It is also proving valuable in the differential diagnoses of various types of gliomas, many of which like the glioblastoma multiforme, have rather characteristic vascular patterns.

Other methods of studying the brain have also been recommended but have gained fewer adherents than the above methods because of some inherent dangers to the patient. Among these are the use of thorium dioxide in the ventricles of the brain; lipiodol introduced into the ventricles of the brain, and a mixture of gas and lipiodol—favored so much by Balado and his pupils.

Some of our present methods may in the course of time be modified, displaced or completely discarded, but there can be no doubt about at least one thing, and that is that however far the science of neuroroentgenology has progressed to date, its greatest development still lies in the future.

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REFERENCES

1. Balado, M., and Carrillo, R. Estudio comparativo de los modernos procedimientos de diagnóstico neuroquirúrgico; resultados de la yodoventriculografía. *Semana méd.*, 1935, *1*, 717–734.
2. Benedikt, M. Das Röntgenlicht im Dienste der Krankheiten des Schädels und des Gehirns und der gerichtlichen Medizin. *Deutsche med. Wchnschr.*, 1902, *28*, 405–407.
3. Bocage, A. E. M. French Patent No. 536464 (1922).
4. Camp, J. D., and Gianturco, C. Simplified technique for roentgenographic examination of optic canals. Am. J. Roentgenol. & Rad. Therapy, 1933, *29*, 547–549.
5. Cannon, W. B. Movements of the stomach observed by roentgen rays. *Am. J. Physiol.*, 1898, *1*, 359.
6. Dandy, W. E. Ventriculography following the injection of air into the cerebral ventricles. *Ann. Surg.*, 1918, *68*, 5–11.
7. Dandy, W. E. Röntgenography of the brain after injection of air into the spinal canal. *Ann. Surg.*, 1919, *70*, 397–403.
8. Dyke, C. G. Indirect signs of brain tumor as noted in routine roentgen examinations; displacement of pineal shadow. Am. J. Roentgenol. & Rad. Therapy, 1930, *23*, 598–606.
9. Egas Moniz. L'encephalographie artérielle, son importance dans la localisation des tumeurs cérébrales. *Rev. neurol.*, 1927, *2*, 72–90.
10. Loman, J., and Myerson, A. Visualization of cerebral vessels by direct intracarotid injection of thorium dioxide (thorotrast). Am. J. Roentgenol. & Rad. Therapy, 1936, *35*, 188–193.
11. Luckett, W. H. Air in the ventricles of the brain following a fracture of the skull. *J. Nerv. & Ment. Dis.*, 1913, *40*, 326–328.
12. Naffziger, H. C. Method for the localization of brain tumors—the pineal shift. *Surg., Gynec. & Obst.*, 1925, *40*, 481–484.
13. Pfeiffer, R. L. New technique for roentgenography of optic canals. Am. J. Roentgenol. & Rad. Therapy, 1933, *29*, 410–415.
14. Robinsohn, I., and Werndorff, R. Ueber die Sauerstoffinsufflation der Gelenke und Weichteile zu radiologisch-diagnostischen Zwecken (mit Demonstration von Röntgenbildern). *Arch. f. phys. Med. u med. Techn.*, 1905–1906, *1*, 22–24.
15. Schüller, A. Roentgen Diagnosis of Diseases of the Head. C. V. Mosby Co., St. Louis, 1918.
16. Stenvers, H. W. Röntgenologie des Felsenbeines und des bitemporalen Schädelbildes mit besonderer Berücksichtigung ihrer klinischen Bedeutung. J. Springer, Berlin, 1928.
17. Towne, E. B. Erosion of petrous bone by acoustic nerve tumor; demonstration by roentgen ray. *Arch. Otolaryng.*, 1926, *4*, 515–519.
18. Vastine, J. H., and Kinney, K. K. Pineal shadow as aid in localization of brain tumors. Am. J. Roentgenol. & Rad. Therapy, 1927, *17*, 320–324.
19. Ziedses des Plantes, B. G. Planigraphie en Subtractie. Röntgenographische Differentiatiemethoden. Kemink en Zoon N. V., Utrecht, 1934.
20. Ziedses des Plantes, B. G. Subtraktion. Eine röntgenographische Methode zur separaten Abbildung bestimmter Teile des Objekts. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1935, *52*, 69–79.

EARLY HISTORY OF ROENTGENOLOGY OF THE SINUSES

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AS HISTORIAN of the American Roentgen Ray Society I have been asked to contribute something appropriate for the semicentennial of the discovery of the roentgen ray. To recount this discovery and its immediate consequences would be only to tell again what has been adequately covered by Glasser.[6] A survey of injuries resulting from the use of the ray by the pioneers would add little to what is already familiar through the writings of Colwell and Russ,[5] and Percy Brown.[2] I have therefore chosen a topic on which I have had the opportunity to unearth some historical material which is apparently not known to many of our profession, and which I believe deserves recording: the evolution of the early roentgen study of the nasal sinuses. It is fairly common knowledge that American roentgenology of the sinuses began with the late Dr. E. W. Caldwell, and it is known to those who were close to Caldwell that he was stimulated by seeing roentgenograms brought over from Germany. But it took considerable investigation to learn the source of those original roentgenograms. I have been able to trace them to their source and shall give this history a little farther on.

The young roentgenologist of today, or the rhinologist who does his own sinus roentgenography, is apt to have little conception of the laborious steps by which the art was developed to the point where it was offered to him. It was not unknown, before this diagnostic aid was available, to have the following sequence of events: frontal pain, density on transillumination, surgical approach with hammer and chisel, with perforation of the cranial cavity because there was no frontal sinus there; meningitis, and no sulfa drugs or penicillin. It was to forestall this unhappy situation that the newly discovered ray was applied to determine whether or not there was a frontal sinus in these patients.

As early as 1896 Scheier[11] reported having localized a bullet in the cranial cavity, not only in lateral projection but in the frontal, but to show a bullet was one thing and to show the outline of the frontal sinuses in the frontal projection was another. In 1902 Beck[1] mentioned frontal views as a matter of routine, but the reproduction of the lateral projection in the reference cited would not lead to much optimism about the value of the frontal view. In 1902 Winckler[13] reproduced excellent frontal exposures of the dried skull, but confessed his inability to produce worthwhile frontal plates of the living. In 1903 Holzknecht[9] praised Winckler[6] for his contribution to the interpretation of lateral roentgenograms but was quite critical of him for failing to produce frontal views of the living. Holzknecht stated that by using better immobilization than Winckler's lateral roentgenograms showed, and coning down the rays with a lead diaphragm, he produced routinely as good frontal roentgenograms on the living as Winckler did on the dried skull.

In 1902 Philip[10] of San Francisco independently duplicated the procedure of Scheier and of Winckler, to determine that his patient had a frontal sinus, and on a lateral roentgenogram noted to have been made by Mr. Cox of the San Francisco Polyclinic that required eight minutes' exposure at a distance of 20 inches, he demonstrated not only that there was a frontal sinus, but that the tip of his exploring sound was in it.

However, the spark that was to activate the development of sinus roentgenology in America was to come in 1904, when Dr. F. C. Ard, returning from a visit to Killian's clinic in Freiburg, brought to Dr. Cornelius G. Coakley in New York "a

plate showing normal frontal sinuses and one in which suppuration could be readily diagnosed. . . . Dr. Ard stated that the patient lay prone on his face, a photographic plate being placed under the forehead and the tube with a compression apparatus placed on the occiput. The time of exposure was stated to be $3\frac{1}{3}$ minutes."[4]

Dr. Caldwell had died five years before it was my privilege to become the assistant of his former associate, Dr. H. M. Imboden, but his spirit was still very much alive in that office in 1923 and is in 1945, and I have a clear mental picture of Dr. Caldwell, and a first-hand vivid recollection of Dr. Coakley. I can easily enough visualize the incident when Coakley held these plates up before Caldwell and probably said "Caldwell, this is what they're doing in Germany. What's the matter with *you* fellows?"

In the basement of Caldwell's office was a fabulous experimental machine shop presided over by Raphael Paroselli, and my technician is Leo Paroselli, Raphael's son. Leo was born in 1905, a year after this incident, and he does not recall any reminiscence of his father's that bears directly upon it. But there is still in Dr. Imboden's possession a sagittal section of a skull mounted on a board with a protractor, prepared, as was all other experimental apparatus of Caldwell's, by Raphael according to Caldwell's specification. This device was illustrated by Dr. P. M. Hickey[8] in his Caldwell Lecture in 1928, and it shows that the optimum angle of projection was 25 degrees, open cephalad. As a matter of fact, Caldwell used angles of from 23 to 28 degrees, depending largely on the shape of the patient's nose. From Caldwell's pencil sketches, Raphael built a light-weight but strong table, capable of being folded up, with a device supporting the head supine on a canvas sling, the tube in Caldwell's own design of tube stand being under the head, and the plate on a celluloid frame over the face. Throughout the five years I was with Dr. Imboden, this original table was in daily use, and I made many roentgenograms for Dr. Coakley, who would naught of anything but glass plates until their manufacture was discontinued.

I had often wondered as to the source of the roentgenograms that went from Ard to Coakley to Caldwell, but only when I searched the literature for 1907 did I find the answer: Goldmann and Killian[7] speak of having seen excellent roentgenograms of the frontal and maxillary sinuses from Prof. Hägler in Basle. "We at once occupied ourselves with the application and the diagnostic value of this method and in 1904 Goldmann exhibited numerous skiagrams before the Congress of South German Laryngologists in Heidelberg. Some of our roentgenograms were taken by Dr. Ard to Coakley in New York, who through further observations fully confirmed the diagnostic significance of our method for diseases of the accessory sinuses of the nose. The great impetus which the handling of particularly the frontal sinuses by the radical operative method of Killian has had makes it in order for us to review our examinations and, on the basis of a large series of cases, to define our standpoint as to the diagnostic value of the roentgen rays, especially for diseases of the frontal, ethmoid, and maxillary sinuses."

"All the (Freiburg) exposures were made in the Diakonissenhaus by Sister Marie Schmelcher, following the directions of Prof. Goldmann."[7] At the time of this publication (1907) the average exposure for frontal roentgenograms in Freiburg was one and a half to two minutes. Caldwell, who before he became a roentgenologist was an outstanding electrical engineer, was making them at this time in twenty to fifty seconds. To the best of my knowledge, the output of the roentgen equipment did not differ materially in the two countries. Caldwell's shorter exposures, therefore, were at the cost of more electrical energy, driving the tubes to the point of breakdown. The Coolidge tube, be it remembered, came in 1913, and roentgenologists old enough to have worked with the old style gas tubes are now relatively few. The gas tube did

give a beautiful roentgenogram because it was free from the parasitic radiation of the stem; it was the most exasperating inanimate object, temperamentally, that man has ever created. Its conductivity would change abruptly in the middle of the exposure. To run such a piece of apparatus for fifty seconds at a load approximating its capacity ruined any number of these tubes. Caldwell[3] speaks of selecting tubes that would stand such a load out of a large number of run of the mill tubes, and then he states that frequently a tube would be destroyed during the exposure. He stated further that the expense of replacing ruined tubes took all the financial return for his early sinus work. In looking back on sinus roentgenology before 1913, therefore, one can only wonder at the excellence of those early roentgenograms made on glass plates. In fact, one can wonder that they had sinus roentgenograms at all.

"The diagnostic value of the X-rays especially for diseases of the frontal, ethmoid, and maxillary sinuses." Thus Goldmann and Killian in 1907. Eloquence can reside in omission as well as in expression. Caldwell's estimate of the value of roentgenology with respect to the sphenoid sinuses was similar to that of Goldmann and Killian. Caldwell studied projections of the sphenoids anteriorly and posteriorly, up and down and sideways, and he refused to give any opinion on the sphenoid sinuses, because he said he was not being paid to guess. Just as some progress has been made in the treatment of arthritis since the time that Osler advised young physicians to run out the back door and jump over the fence when a patient came in with arthritis, because he would earn more ultimate gratitude from the patient by so doing, some progress has been made in the intervening thirty-eight years on the roentgen diagnosis of the sphenoid sinuses. But an account of it has no place in a consideration of the early history of roentgenology of the sinuses.

The transition between the early period and the modern period in this branch of roentgenology, it seems to me, is just about when Waters[12] contributed the angle which bears his name. We are prone to think of the Waters position as having its principal value in the improved visualization of the antra, the petrous shadows being thrown below the antral shadows, but Waters called attention to its value also in showing the anterior and the posterior ethmoid cells. Those who are accustomed to using both the Waters and the Caldwell projection would be very loath to rely on either one without the other.

The original posteroanterior projection will probably long be known in this country as Caldwell's angle, and he did work out the angle for it independently; but approximately the same angle he established had been used a little before him by Goldmann in Freiburg, who acknowledged the priority of Hägler in Basle. It was Basle where the Basle Nomina Anatomica originated, dedicated to an attempt to supplant proper names in anatomy. However, as long as roentgen rays come out of Coolidge tubes, we shall probably continue to pay tribute to Caldwell and to Waters as among the earliest and still the most promiment contributors to roentgenology of the sinuses in the United States.

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REFERENCES

1. Beck, Carl. Die Röntgenstrahlen im Dienste der Chirurgie. Seitz und Schauer, München, 1902.
2. Brown, Percy. American Martyrs to Science through the Roentgen Rays. Charles C Thomas, Springfield, Illinois, 1936.
3. Caldwell, E. W. Further observations on roentgen-ray examination of accessory nasal sinuses. *Laryngoscope*, 1908, *18*, 853–859.
4. Coakley, C. G. Skiagraphy as an aid in diagnosis and treatment of diseases of accessory sinuses of the nose. *Ann. Otol., Rhinol. & Laryngol.*, 1905, *14*, 16–20.
5. Colwell, H. A., and Russ, Sidney. X-ray and Radium Injuries; Prevention and Treatment. Oxford University Press, London, 1934.
6. Glasser, Otto, Editor. The Science of Radiology. Charles C Thomas, Springfield, Illinois, 1933.

7. Goldmann, E. E., and Killian, G. Ueber die Verwendung der X-Strahlen für die Bestimmung der nasalen Nebenhöhlen und ihrer Erkrankungen. *Beitr. z. klin. Chir.*, 1907, *54*, 1–22.

8. Hickey, P. M. Caldwell Lecture, 1928. Am. J. Roentgenol. & Rad. Therapy, 1931, *25*, 177–195.

9. Holzknecht, G. Bemerkungen zum Aufsatze: "In welcher Weise kann bei eitrigen Erkrankungen der oberen nasalen Nebenräume das Röntgenbild des Gesichtsschädels den Operationsplan, diese Hohlräume durch äussere Eingriffe freizulegen, modifizieren" von Winkler. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1902–1903, *6*, 194–195.

10. Philip, J. H. The x-ray in determining the limits of frontal sinus. *J. Am. M. Ass.*, 1902, *38*, 764–765.

11. Scheier, Max. Bibliothek der gesammten medizinischen Wissenschaften. Edited by A. Drasche. Karl Prochaska, Wien, 1899. Volume on Ohren-, Nasen-, Rachen- und Kehlkopfkrankheiten, pp. 571–588.

12. Waters, C. A., and Waldron, C. W. Roentgenology of accessory nasal sinuses describing a modification of the occipito-frontal position. Am. J. Roentgenol., 1914–1915, *2*, 633–639.

13. Winckler, E. Die Orientierung auf dem Röntgenbilde des Gesichtsschädels und das Studium der oberen nasalen Nebenhöhlen auf demselben. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1901–1902, *5*, 147–157.

HISTORY OF THE ROENTGEN RAY IN THE STUDY OF THE HEART*

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VERY soon after the discovery of the roentgen ray, the heart and great vessels were submitted to examination by its use. There was no need for complicated procedures; the conditions of contrast were optimal, and there was no inconvenience to the patient. To do justice to even the pioneer workers in an article of this scope is obviously impossible when one considers that the list of books and pamphlets on the roentgen ray published during 1896—the year after its discovery—as given in Glasser's book,[3] totals 1,044 items.

The first period of investigation extends to perhaps the year 1900; many instructive cases were published that dealt chiefly with single observations. Details were searched for, the principles of projections were realized, and even as early as 1896 mention is made of calcifications in the aorta by Levy,[11] and in the peripheral vessels by Hoppe-Seyler.[7]

By 1900–1901 exact methods were developed and a systematic evaluation of the physiological foundations had taken place. The introduction of the orthodiagraphic method by Moritz[12] and Béclère,[1] the analysis of the normal and pathological aorta by Holzknecht,[5,6] and the correlation of roentgenologic and clinical findings by Williams[16] represent the great advances made at that time. It is instructive to read in Williams' book his pointing out the errors in percussion, his reports on follow-up studies on effective treatment, and his stressing of the diagnostic and prognostic appearance of the lesser circulation. One of his important observations refers to what we would now call the beriberi heart.

In 1905 Köhler[9] introduced the teleroentgenographic method, which soon became a common possession.

Subsequently a systematic evaluation of the pathologic conditions of the heart and great vessels developed, with emphasis being placed on certain constitutional features, and there was an increasing correlation with anatomical and physiological data. To refer to the many small mosaics that have ultimately led to the integrated science of today would require the writing of a treatise in this field. Therefore only a few lines of development are pointed out.

Although many excellent observations were made as to the movement of the cardiovascular silhouette, objective registration did not arrive until 1911 with kymography, and among the contributors to this technique were Sabat,[15] and Goett and Rosenthal.[4]

A better understanding of the inner topography of the cardiovascular silhouette has been obtained in a twofold way: first, by correlating in a systematic fashion the roentgenologic appearance with anatomic sections (Koch and Wieck[8]); second, by opacification of the heart and great vessels in the cadaver—of the right-sided cavities and the lesser circulation, and of the left-sided cavities and aorta, respectively—and the appropriate use of various views (Laubry, Cottenot, Routier and Heim de Balsac[10]).

In the living, angiocardiography was introduced by Forssmann,[2] and valuable findings were obtained by the method developed by Robb and Steinberg.[14] The plastic reconstruction of the heart by Palmieri[13] was also an important contribution.

Although this brief résumé seems to stress the technical aspects of progress in cardiology, it must not be forgotten that the advance attained and the refined diagnostic possibilities afforded by the methods in use today have come from a healthy interplay between men who were primarily

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interested in technical and morphological problems and other men who could offer their critical, anatomical, physiological and clinical experience. Almost all of the contributions—as one studies them in retrospect—have been a mixture of truth and error, but the truth has been retained through an interesting and peculiar process of sifting. Sooner or later the names of the individual contributors to a science fade as the science grows, and this is as it should be, for science is a structure in the process of building. When the temple is completed, we admire its beauty but think not of the laborers who laid the stones.

The celebration of anniversaries is a wholesome thing, for it freshens our sense of indebtedness to our forerunners but, by the law of opposites, it leads to anticipation as well as to retrospect—to a surmise of the one hundredth anniversary of Röntgen's discovery and the hope that the cardiologists of that day will have completed their study of cardiac pathology and will be celebrating victories in its prevention.

REFERENCES

1. Béclère, A. Sur la mensuration de l'aire du coeur a l'aide des rayons de Röntgen; principe d'une méthode nouvelle. *Bull. et mém. Soc. méd. d. hôp. de Paris*, 1900, *17*, 677.
2. Forssmann, W. Ueber Kontrastdarstellung der Höhlen des lebenden rechten Herzens und der Lungenschlagader. *München. med. Wchnschr.*, 1931, *78*, 489–492.
3. Glasser, O. Wilhelm Conrad Röntgen and the Early History of the Roentgen Rays. Charles C Thomas, Springfield, Illinois, 1934.
4. Goett, T., and Rosenthal, J. Ueber ein Verfahren zur Darstellung der Herzbewegung mittels Röntgenstrahlen (Röntgenkymographie). *München. med. Wchnschr.*, 1912, *59*, 2033.
5. Holzknecht, G. Das radiographische Verhalten der normalen Brustaorta. *Wien. klin. Wchnschr.*, 1900, *13*, 225.
6. Holzknecht, G. Die röntgenologische Diagnostik der Erkrankungen der Brusteingeweide. Gräfe und Sillem, Hamburg, 1901.
7. Hoppe-Seyler, G. Ueber die Verwendung der Röntgen-Strahlen zur Diagnose der Arteriosklerose. *München. med. Wchnschr.*, 1896, *43*, 316.
8. Koch, W., and Wieck, W. Anatomische Analyse des Röntgenbildschattens des Herzens und der Interlobärspalten der Lungen. Gustav Fischer, Jena, 1930.
9. Köhler, A. Die Herstellung fast orthodiagraphischer Herzphotogramme mittels Röntgeninstrumentarien mit kleiner Elektrizitatsquelle. *Wien. klin. Rundschau*, 1905, *19*, 279.
10. Laubry, C., Cottenot, P., Routier, D., and Heim de Balsac, R. Radiologie clinique du coeur et des gros vaisseaux. Masson et Cie, Paris, 1939.
11. Levy, M. Die Durchleuchtung des menschlichen Körpers mittels Röntgenstrahlen zu medizinisch-diagnostischen Zwecken. A. Hirschwald, Berlin, 1896.
12. Moritz, F. Eine einfache Methode, im beim Röntgenverfahren aus den Schattenprojectionen die wahre Grösse der Gegenstände zu ermitteln und die Bestimmung der Herzgrösse nach diesem Verfahren. *Verhandl. d. Kong. f. innere Med.*, 1900, 601.
13. Palmieri, G. G. Sulla possibilitá de ricostruire il cuore in plastica dal vivente con il sussidio dei raggi X. *Malat. d. cuore*, 1920, *4*, 69–76.
14. Robb, G. P., and Steinberg, I. Practical method of visualization of chambers of the heart, the pulmonary circulation, and the great blood vessels in man. *J. Clin. Investigation*, 1938, *17*, 507. Also, Visualization of chambers of heart, pulmonary circulation, and great blood vessels in man; practical method. Am. J. Roentgenol. & Rad. Therapy, 1939, *41*, 1–17.
15. Sabat, B. Ueber ein Verfahren der röntgenographischen Darstellung der Bewegungen innerer Organe (des Herzens, der Aorta, des Zwerchfells). *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1913, *20*, 42–44. Also, Ueber ein Verfahren der röntgenographischen Darstellung der Bewegungen des Zwerchfells, des Herzens, der Aorta. *Lwow. tygodn. lek.*, 1911, *6*, No. 28.
16. Williams, F. H. The Roentgen Rays in Medicine and Surgery as an Aid in Diagnosis and as a Therapeutic Agent. Macmillan Co., New York, 1901.

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THE HISTORY OF THE USE OF THE ROENTGEN RAY IN WARFARE

CALDWELL-CARMAN LECTURE, 1944*

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DETROIT, MICHIGAN

WITH the passing of years the personality of a man recedes into the background and his ultimate place in history is determined by the contributions which he has made to science and society. While Carman did not create fluoroscopy he took this as a method of examination and perfected it in the study of the gastrointestinal tract and transmitted it to us as a fine heritage. And no matter how we in these later years change slightly here and there this method of study, primarily it is Carman's in a new phase or variation.

Caldwell was one of those rare individuals who combined a scientific and a mechanical attitude of mind toward the solution of many of the difficult problems in the early days of roentgen diagnosis and therapy. His position in the roentgenological world stands on a sure footing. Not only did he contribute mightily to the solution of the diagnostic problems which confronted roentgenologists in the early days but his knowledge of engineering enabled him to help solve many of the mechanical problems of those working in roentgenology, and many of the gadgets which we use today in the examination of patients had their primary inception in the mind of Eugene Caldwell. These two societies honor themselves in honoring the memory of Eugene Caldwell and Russell Carman.

In normal times one might choose for the Caldwell-Carman Lecture a subject of more scientific interest but in these times when all our thoughts and actions are geared to total war, I thought it would be interesting to sketch the history of the uses of the roentgen ray in warfare.

ETHIOPIAN CAMPAIGN

The science of roentgenology made its appearance late on the horizon of medicine and surgery. The possibility of its use in warfare was quickly seized upon, and its first practical employment in war surgery was in the examination of some of the soldiers returning from Italy's ill fated Ethiopian campaign where the Italian Army suffered a crushing defeat by the Ethiopians at Adowa on March 1, 1896. The examinations were made by Lieutenant Colonel Alvaro[2] at the Military Hospital at Naples in May, 1896. The roentgen-ray apparatus which he used was not the primitive apparatus of Röntgen since subsequent discoveries permitted modifications and amplifications. It consisted of a series of accumulators connected with an interruptor and commutator; a Ruhmkorff coil and a Crookes tube, not oblong in form but pear shaped, through which several metallic wires were run, one of which was fastened to a small concave disk serving as cathode.

The procedure of practical application of the roentgen rays was described as follows: One takes a prepared photographic plate, places it in several layers of black paper, then puts it in a cardboard or wooden cassette, or on a small taboret in such a way that the impressed gelatinous surface is toward and underneath the part of the body of which the shadow is to be taken, it being fixed in this position with gauze. Above is placed the Crookes tube at a distance of 20 to 30 cm., the current being generated by the Ruhmkorff coil.

* Delivered at the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, Chicago, Ill., Sept. 24–29, 1944.

After twenty minutes, or a good half hour or longer, according to the potential of the current, and the nature, thickness and density of the part, one obtains a negative with a relative white shadow on a black base.

The two cases which were the basis of Alvaro's report were wounded soldiers returned from the battle front at Ethiopia. Fortunately, these two soldiers were wounded in the forearms which rendered their examination fairly easy, considering the feebleness of the equipment. The projectiles were removed following the roentgen studies and the wounds promptly healed. Attempts had previously been made to remove these bullets but they were unsuccessful until the roentgen ray was used in their exact localization.

Attention was called by Lieutenant Colonel Alvaro to the valuable help which the roentgen rays could give to the surgeon, especially when there was a question of determining the position of a foreign body, or of diagnosing a bone disease, or judging the form of a fracture, or studying the deformity of the skeleton and the formation of internal concretions. He was possessed apparently of a prophetic vision for in these faroff days he sensed the possibilities of the roentgen ray not only in military but also in civilian hospital use and predicted for it a great future.

From these early beginnings in the use of the roentgen ray in warfare we have travelled a long way and more recently Naples has seen other soldiers and other roentgen-ray equipment land at her ports.

GRECO-TURKISH WAR—1897

The Mediterranean basin in those years, as in these later years, was the theater of wars and quickly upon the heels of the Ethiopian War came the Greco-Turkish War of 1897. As in all wars in which the Balkan states were involved, the great powers of Europe took sides and in the Greco-Turkish War the German sympathies and their support were with the Turks, while Russia, England and France lent their support to the Greeks.

It was during this war that the first opportunity for the study of the usefulness of the roentgen rays in hospitals located close to the front was provided. The Central Committee of the German Red Cross sent a hospital unit which was located in Constantinople. At the disposal of this unit was placed a roentgen apparatus. Dr. Küttner who accompanied this hospital reported his experiences in the use of the roentgen ray.[17] He found that it was of great help in establishing the position of the embedded bullets, immensely facilitating their removal, and it was particularly helpful in cases of osteomyelitis or draining wounds, in determining the extent of the fractures and the presence or absence of the bullets or fragments of lead or clothing. The roentgen procedure was found of great value in the estimation of injuries to the nervous system. Especially where there was a severe paralysis they were able with the roentgen ray to determine whether the paralysis was a result of compression of the spinal cord by dislocated bone fragments or by bullet injuries, thereby determining the advisability of an operation. Even in paralysis of the peripheral nerves it was possible to differentiate between injury due to pressure from bone fragments and injuries due directly to a penetrating bullet.

Küttner discussed the importance of the roentgen ray and also the feasibility of its use at advanced line hospitals. From his experience with the bulky type of machine which they used he concluded that the roentgen ray could only be employed in the reserve or base hospitals and not in a field or evacuation hospital.

The British Red Cross also sent hospital units for the aid of the sick and wounded of the Greek army. Two hospitals were established, one in a villa at Phalerum and the other at Chalcis.[1] Both of these cities were frightfully overcrowded with thou-

sands of refugees, which complicated the proper handling of the sick and wounded. The British units were supplied with a powerful coil and all the other essentials for roentgen-ray work and, since it was the only apparatus of its kind in Greece, these hospitals received cases from other surgeons to supplement their own and were in a position to gain a large experience in bullet wound cases. The only difficulty that was experienced with the roentgen-ray apparatus was with the batteries, the extreme heat melting the pitch of the partitions between the cells. The coil which the British surgeons used gave a nominal 10 inch spark. They used only three Crookes tubes throughout the campaign but from their experience they thought it was advisable to have a good reserve of tubes. The equipment also included a fluoroscopic screen which proved the means of saving much time and which is stated was probably even more necessary in war than in work elsewhere.

Some of the difficulties in the use of the roentgen rays in war as they presented themselves to the British unit were the great weight of the coil and secondary battery, the absolute necessity of having a source of electric supply near at hand to recharge the batteries, the fragility of the Crookes tubes and glass negatives, the danger of carrying strong sulphuric acid, the difficulty of sparing the space and of making an efficient dark room with good water supply, besides the general delicacy and liability to derangement of the whole apparatus. A more amusing source of difficulty in this particular campaign was the superstition of the natives. They looked on the whole affair as the work of the Devil which made it difficult to take a skiagram when the subject was constantly crossing himself unless strictly watched.

The problem of the source of electricity was solved by the fact that the hospital was at Phalerum and they were able to obtain an electric supply from *H.M.S. Rodney*. The hospital at Phalerum was also close enought to Athens to enable the Greek surgeons to send up such cases as needed roentgen studies.

During the Greco-Turkish war the Mauser rifles and the Martini-Henry rifles were used and the bullets from these then modern implements of war were much less frequently found in the body due to the high velocity of the bullet. The hole of entrance of the bullet was extremely small. Suppuration of the wounds was generally due to pieces of clothing carried into the tissues. Wounds of the lung by these modern bullets ran a comparatively favorable course. Lead bullets were used in this campaign and characteristically they left particles of lead along their paths.

It was the impression of the British surgeons and roentgenographers that the roentgen apparatus would prove of no use on the field, first because of the size and bulk of the machine, and second, they thought that its use at the front might be an incentive to surgeons to premature operations in bad surroundings.

THE TIRAH CAMPAIGN—1896

The sympathy of the English for the Greek Nation during the Greco-Turkish War caused deep annoyance and indignation among the Turks. This feeling was propagated through the Mohammedan countries. So, at far away Peshawar in Northern India, near the Khyber Pass, agents from Constantinople made their appearance, stirring unrest among the tribes and members of the Mohammedan faith in that part of the world.[21]

Khyber Pass is one of the most important mountain passes in the world[14] (Fig. 1). It leads from Afghanistan into India and is a narrow defile winding between cliffs 600 to 1,000 feet high, stretching up to more lofty mountains beyond (Fig. 2). Perhaps no other pass in the world has possessed so much strategic importance or retains so many historic associations as this gateway to the plains of India. The great invasions of India which have oc-

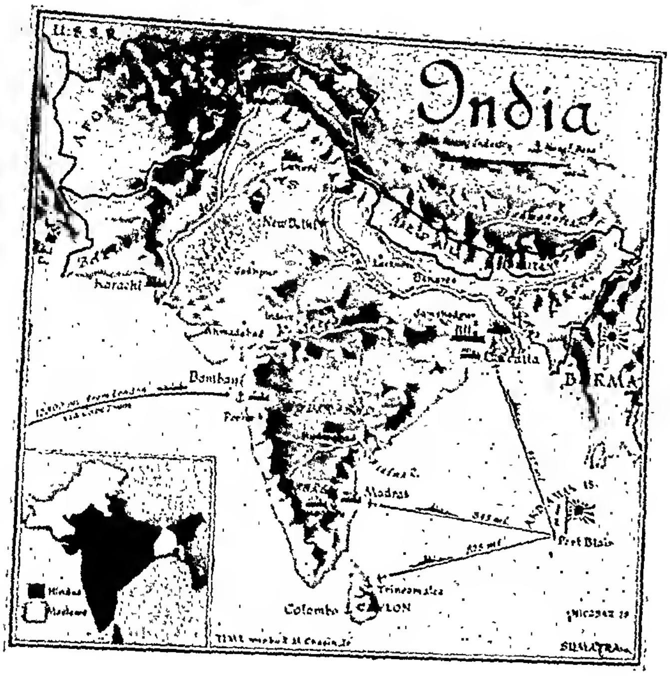

Fig. 1. Reproduced, by permission, from *Time*, September 14, 1942.

curred in this area have gone through it. Since this Pass lay in such a strategic position and was so important to the British in India, it became necessary for the British to negotiate with the local tribes, the Afridi and Orakzai, for its free use to safeguard the passage into India. After many attempts at appeasement of these warlike tribes, the British succeeded in obtaining at least a temporary cessation of hostilities prior to 1897. The scheme which was adopted was an arrangement with the Afridis by which they agreed to keep open the Khyber Pass on behalf of the British Government. Several forts were built and to garrison them a corps of riflemen was formed, entirely composed of tribesmen living in the neighborhood of the Pass. For a while these natives gave the regular troops of the Indian Army great assistance.[20] However, following the agitation among the Mohammedans, the Afridis and the Orakzais decided to revolt against the British and they seized the forts in the Khyber Pass, closing it to travellers and to military transports. The British-Indian Government, realizing the importance of the Khyber Pass itself and the menace of the revolt among the natives, sent an expedition to quell the uprising. This campaign is known as the Tirah Campaign.

The Tirah country, lying high in the plateaus of the Skofed mountains (Fig. 3) was at that time unknown to the outside world;[15] it served as the summer resting place of the native Afridis and Orakzais (Fig. 4 and 5). No white man, certainly no troops other than native troops, had ever invaded the region until the armies under the leadership of General Sir William Lockhart began their expedition into the territory in October, 1897.[16]

Twenty-three field hospitals altogether were mobilized for service in the Tirah Campaign. The wild, entirely roadless country in which the military operations were conducted increased the difficulties with which the medical department had to contend in making arrangements for the care, treatment and transport of the wounded and sick. Many of the wounded had to be carried on stretchers and to be escorted all the way throughout the hostile

Fig. 2. The Dwatoi Defile. Reproduced from Warburton.[21]

territory, experiences not unlike those in the present campaign in India and Burma.

One notable feature of the medical arrangements was the use of roentgen rays for the first time on the field of battle. They were found of the greatest value in locating bullets and splinters of lead. The apparatus was brought out (entirely at his own expense) and operated by Surgeon Major W. C. Beevor,[4] to whom all the credit of the innovation is due. From his experience in the Tirah Campaign, Major Beevor called attention to the importance of the organization and the type of apparatus and materials to be used in warfare. The first desideratum in the construction of all apparatus for military work, he concluded, is that they be "get-at-able," thus enabling one to renovate the inevitable defects of wear and tear. Every portion of the apparatus should be easy of access; the coils, condensers, connections, etc., should all be packed in cases that can be opened and inspected in a moment's notice without special instruments. In addition, the operator of the roentgen apparatus should be independent of help.

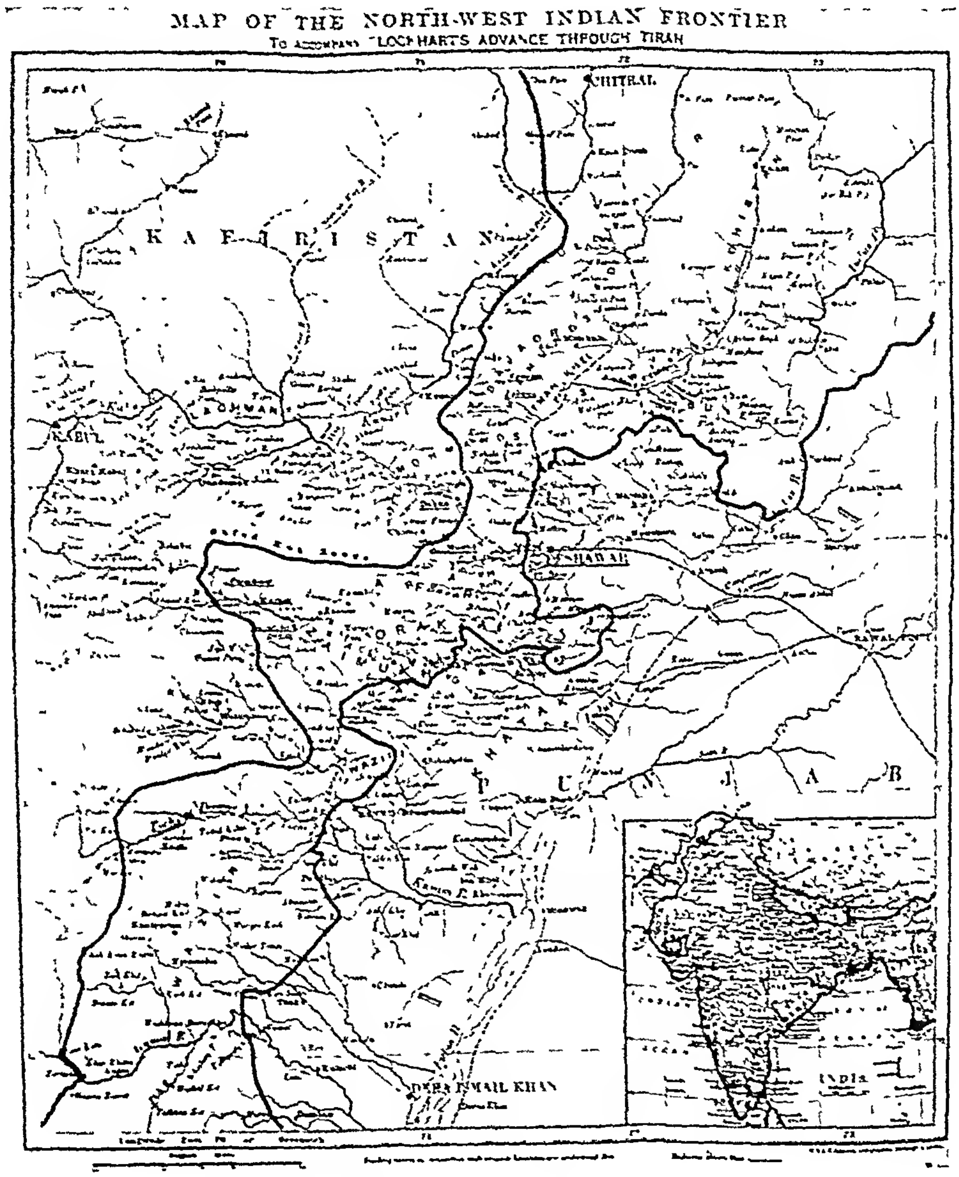

Fig. 3. Reproduced from Shadwell.[20]

Beevor was supplied with only three tubes. They were used in more than two hundred cases in Tirah; they went all through the rough transport country and they landed back at Rawal Pindi in as good

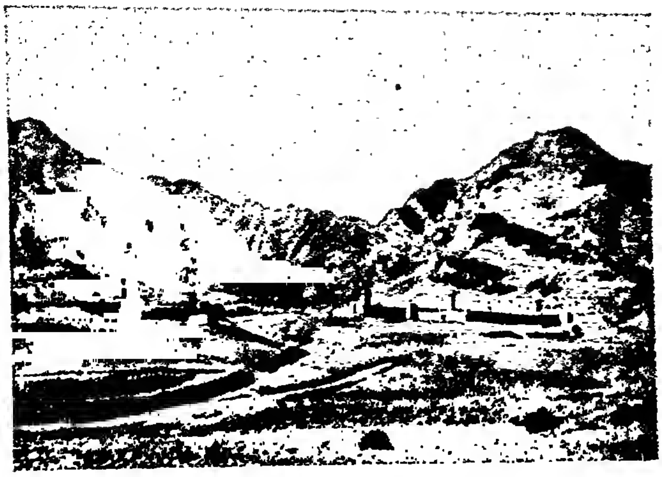

Fig. 4. Afridi villages below Ali Masjid. Reproduced from Warburton.[21]

working order as when they were taken out.

The question of transport for the equipment offered some difficulties, but even in the wildest part of the country they were able to transport it and to use it effectively in the examination of the injured. Its greatest value, of course, was in the localization of bullets and other foreign bodies and also in determining the extent of the injury to the bone structures. From his experience, Major Beevor concluded that every civilized nation is duty bound to supply its wounded in war with roentgen apparatus, not only at base hospitals but in the field.

After trying every kind of transport in India—mules, camels, wheeled vehicles, etc.—Beevor found that the safest and most satisfactory was human transport. In Tirah he employed Dhoolie bearers and they carried the whole apparatus from Bagh Camp in Tirah, down the defile to Dwatoi, and down the Bara Valley to Peshawar without injury. Parts of this march were beset with difficulties seldom experienced in any kind of warfare. They encountered rocks, icy cold water, rapid torrents, frost and snow which did not interfere in any way with the apparatus.

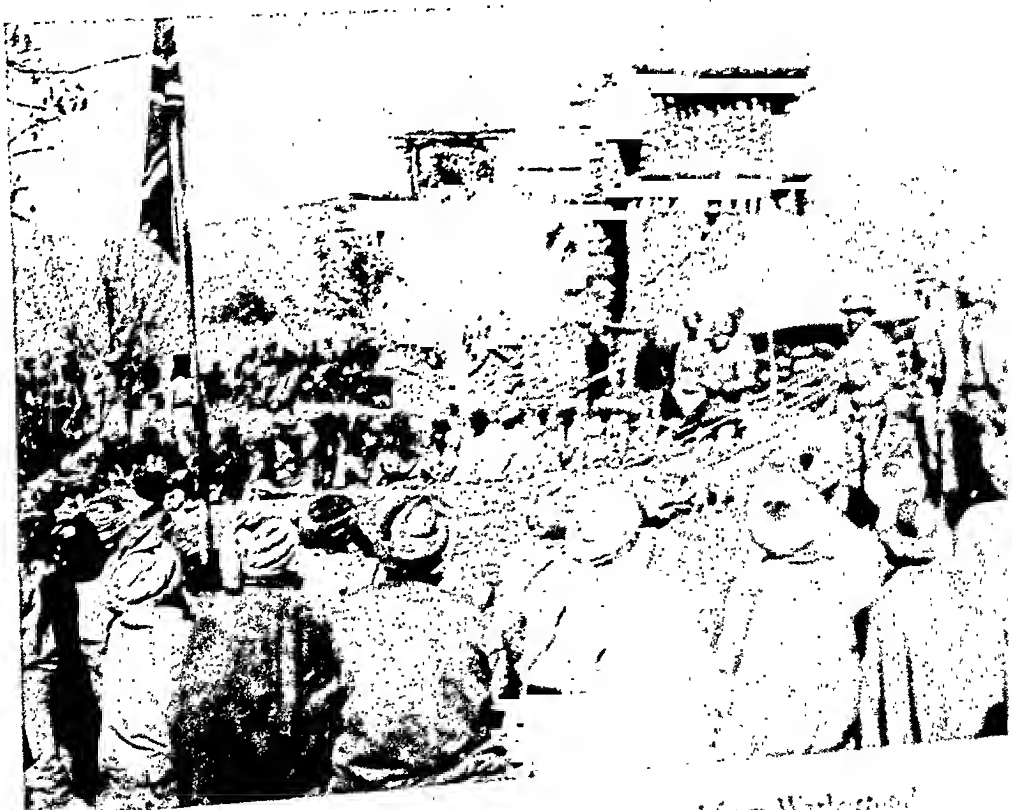

Fig. 5. Tirah. The Orakzai Jirgah. Reproduced from Warburton.[21]

The greatest problem involved in operating the apparatus was the generation of electricity. The only means Beevor had at Tirah was a heavy and cumbersome primary battery worked by a mixture of bichromate of potash and sulphuric acid. The latter was too dangerous for [illegible] transport unless accompanied by [illegible] especially to look after it. [illegible] condemned this form of battery [illegible]

work and recommended the employment of a hand dynamo and portable accumulator. This combination had many advantages—it could stand rough transport and in case one got out of order the other could be substituted.

As in the former campaigns, the fluorescent screen seemed the most important part of the apparatus. The screen surface was protected with a layer of celanite and the whole was enclosed in an aluminum case.

In roentgenographic work the glass plates were found to be most satisfactory, in spite of danger of breakage in transport. Beevor had three dozen at the beginning of the Tirah Campaign and through all the adverse conditions they proved satisfactory, giving at the end of four months' rough travel as good results as at the beginning.

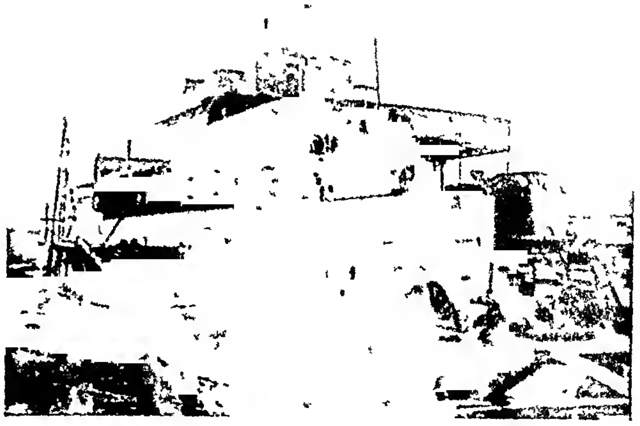

Fig. 7. The new stern-wheel gunboat in the shipyard at Wyvenhoe. Reproduced from Churchill.[10]

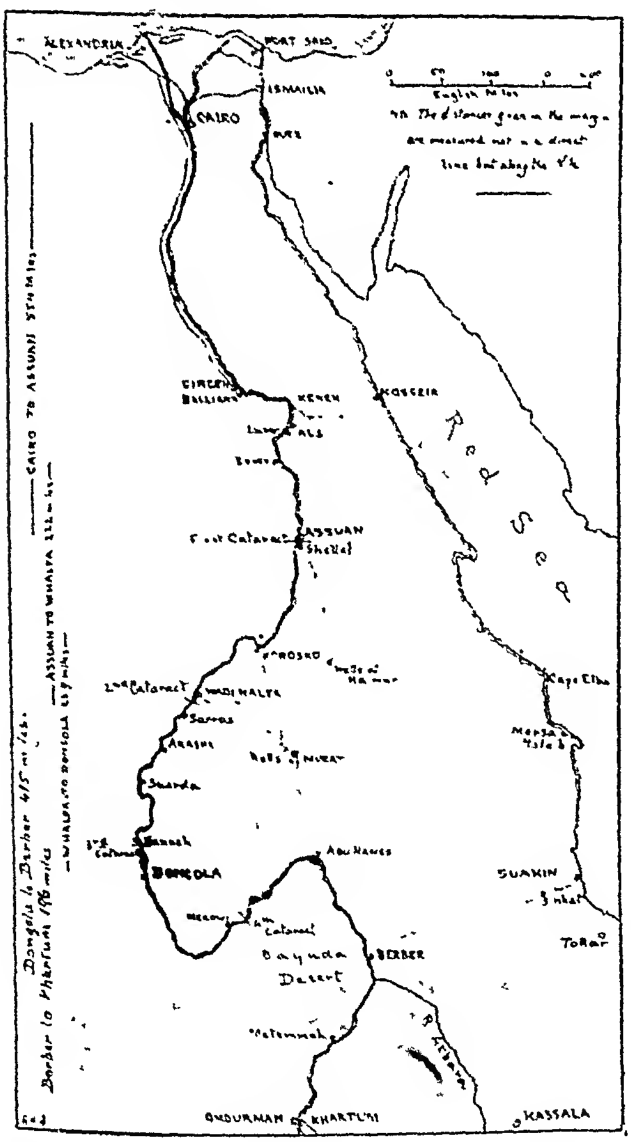

Fig. 6. Sketch map. Distances and principal points in the Nile Valley. Reproduced from Churchill.[10]

WAR OF THE SOUDAN—1896–1898
(THE RIVER WAR)

The Tirah Campaign was in progress at the time when the financial state of the Egyptian government, under the supervision of the British and their collaborators, had reached such a point that attention could be given to the recurrent outbreaks of hostility among the tribes in the Soudan (Fig. 6). This decision was made the easier by the fact that the assassination of an Englishman, General Gordon, several years before at Kartoun by the natives of the Soudan had rankled in the hearts of the British and had been a source of considerable controversy in the British government. It was decided to send an expeditionary force up the Nile to subdue and conquer the natives in the Soudan, and Lord Kitchener was chosen as the head of the expedition. His organization consisted not only of British units but of well trained Egyptian military units and a certain number of natives. The journey up the Nile was made in slow stages accompanied by vessels suitable for transport on the Nile. In this heterogeneous army there were two men whose subsequent activities were to influence the world—Winston

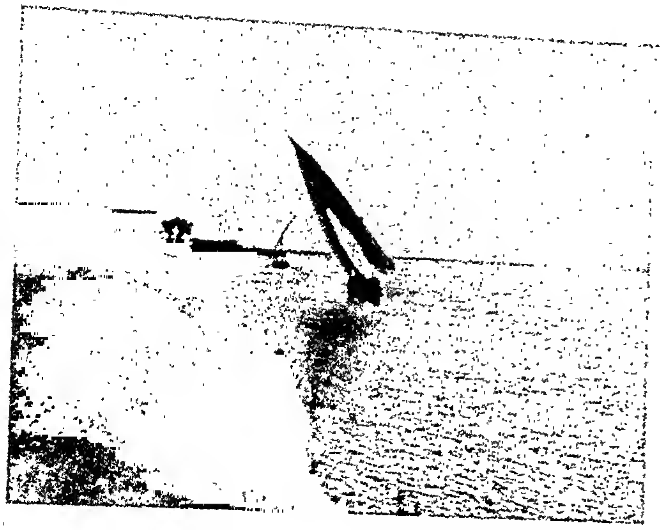

Fig. 8. The Nile at Abadieh. Eight miles north of Berber, where advanced base Surgical Hospital was situated, and also headquarters of x-ray work. Reproduced from Battersby.[3]

Churchill,[10] an officer in the cavalry, and a junior naval lieutenant in command of one of the gunboats (Fig. 7), Lieutenant Beatty, afterwards Admiral Beatty of Jutland fame.

Numerous engagements were fought in the journey up the Nile and in each of these the natives were defeated. They continued to retreat up the Nile to their main headquarters at Omdurman. It was at Omdurman that the Dervishes received their crushing defeat at the hands of Lord Kitchener and his army, which has been described as "the most signal triumph ever gained by the arms of science over barbarians. Within the space of five hours the strongest and best-armed savage army yet arrayed against a modern European power had been destroyed and dispersed, with hardly any difficulty, comparatively small risk, and insignificant loss to the victors." It is also of interest to note that among these arms of science was a roentgen-ray apparatus.

The man in charge of the apparatus was Major Battersby.[3] Before he left Cairo he took the precaution of having very thick felt covers made to surround the outer boxes containing the coils and storage batteries, and, by keeping them constantly wet, the internal temperature of the coils was considerably reduced, as the evaporation in the Soudan was very rapid, the temperature varying from 100° to 122° F. in the shade.

Between Wady Halfa and Abadieh, the site of the base hospital (Fig. 8), all the apparatus had to travel for two days and a night in an open truck, exposed during the daytime to the fierce heat of a blazing sun. By keeping the felt wet every two hours, they reached their journey's end without mishap to the apparatus (Fig. 9).

In the Soudan some 60 observations were made by the screen and plates. In bullet wounds of the upper or lower extremities anteroposterior and lateral views (Figs. 10 and 11) gave sufficiently comprehensive information as to the position of the bullet but in the deeper structures the best results were obtained by a modification of Mackenzie-Davidson's localizing apparatus (Fig. 12).

As in the Tirah Campaign the roentgen-ray outfit which accompanied the army in the River War had to be portable and suitable for mule, camel or human transport, as often during the journey up the Nile, narrow defiles and mountainous passes had to be traversed. One of the most serious difficulties, ever present in all campaigns, was the generating of the primary electrical current for charging the storage batteries or working the coil direct. In the Soudan Campaign a small dynamo driven by means of a tandem bicycle (Fig. 13) answered this problem admirably and was readily transported by rail and

Fig. 9. Major Battersby [illegible] radiograph. Reproduced from Battersby.

Fig. 10

Fig. 11

Figs. 10 and 11. Bullet in knee (front view, Fig. 10); bullet in knee (side view, Fig. 11). Reproduced from Battersby.[3]

river to its destination at the hospital at Abadieh.

The roentgen-ray outfit consisted of two 10 inch and one 6 inch coil and these, with the other necessary electrical instruments, were enclosed in a strong oak box. While the apparatus was most complete and satisfactory, it was for the requirements of field service too heavy for camel or mule transport. Consequently a special arrangement of ropes was made, by which means, and by the aid of a long pole, it could be carried on the shoulders of four men. The apparatus further consisted of a storage battery with separate cells which proved more useful than having them fixed in a wooden case, because if a cell became injured or a plate buckled, it could be taken out of the circuit and a spare one substituted.

Battersby also brought with him four 10 inch ordinary bianodic focus tubes. These were personally tested before leaving. Two of these tubes did most excellent and extensive work, one being better for screen work and the other for roentgenography.

The fluorescent screen was found most useful at night, but unsatisfactory during

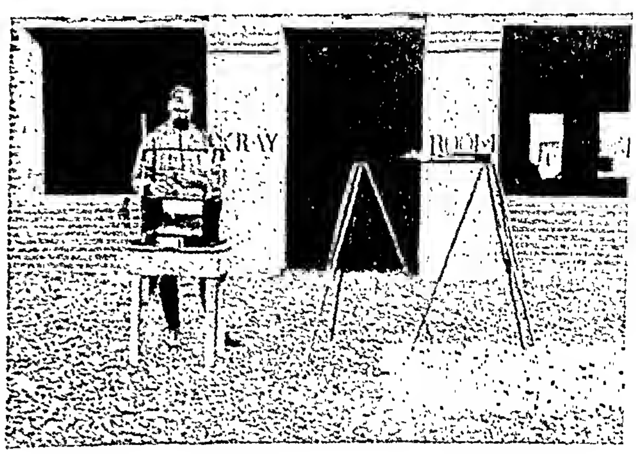

Fig. 12. Localizing apparatus. Reproduced from Battersby.[3]

the day owing to the intense sunlight which, do what they would, seemed to penetrate the hood, no darkroom being available. The surface of the screen was protected by a layer of celluloid, which in a warm and dusty climate was a matter of no mean importance.

The photographic materials and developers in these early days were rather crude and much had to be learned in this regard. Glass plates alone gave satisfactory results.

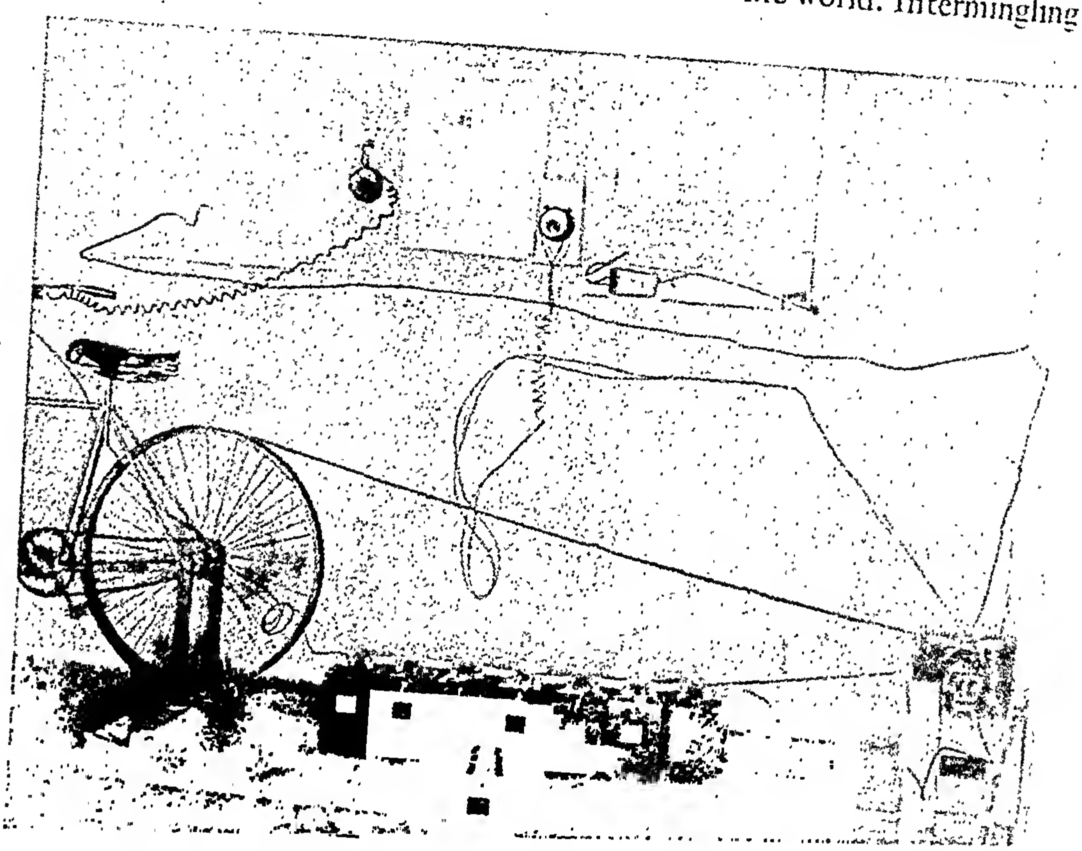

FIG. 13. Method by which electricity was generated for charging storage batteries. Reproduced from Battersby.[3]

The total number of casualties in the British Army at the Battle of Omdurman was 175. Of these, 121 were conveyed to the surgical hospital at Abadieh. Of this number there were 21 cases in which the bullet could not be found or its absence proved by ordinary methods. In 20 of these 21 cases an accurate diagnosis was arrived at with the help of the roentgen ray.

THE GREAT BOER WAR—1899

These little wars in which the roentgen ray became a camp follower were followed by the Great Boer War in 1899. If one looks at the map of South Africa, he will see there in the very center of the British possessions a great stretch of the two republics which comprise the lands of the Boer nation (Fig. 14). The Boers are the descendants of those hardy Dutchmen who for fifty years defended themselves against Spain which was then the greatest power in the world. Intermingling with this Dutch strain were the French Huguenots who left their country at the time of the revocation of the Edict of Nantes. These virile formidable people and their progeny had for seven generations trained themselves in a constant warfare against savage men and ferocious beasts under circumstances which no weakling could survive. They became a law into themselves, recognizing no government except that which they themselves had established. These Dutch emigrants made their first landings at the Cape of Good Hope in 1652 and for one hundred years the colony spread gradually over the huge expanse of veldt which lay to the north. They remained happy and contented in their new

country until the world was suddenly startled by the announcement of the enormous gold and diamond mines in that part of South Africa. The Boers then saw their lands being occupied by outsiders and they set about to prevent this by the issuing of certain laws governing citizenship and it was the imposition of these laws and certain other small episodes which ultimately brought about the South African or the Great Boer War with England.

Conan Doyle,[11] in commenting on this war says: "Our military history has largely consisted in our conflicts with France, but Napoleon and all his veterans have never treated us so roughly as these hard-bitten farmers with their ancient theology and their inconveniently modern rifles."

The British, contrary to their thought, soon found themselves pitted against a formidable foe and had made inadequate preparations for it. The War of the Soudan having been completed, the medical units, together with the roentgen-ray equipment which had been used in that war, were ordered to South Africa.

The Siege of Ladysmith in the Boer War furnished the first occasion in which roentgenography was attempted under such conditions. It was here also that actual work was first done under shell fire for any long period.

Lieutenant Bruce[6] of the British Army who was stationed in Cairo, received his orders to proceed to Natal and to take a complete roentgen-ray unit. This unit was available but to arrange for a supply of electricity was not so easy. From his

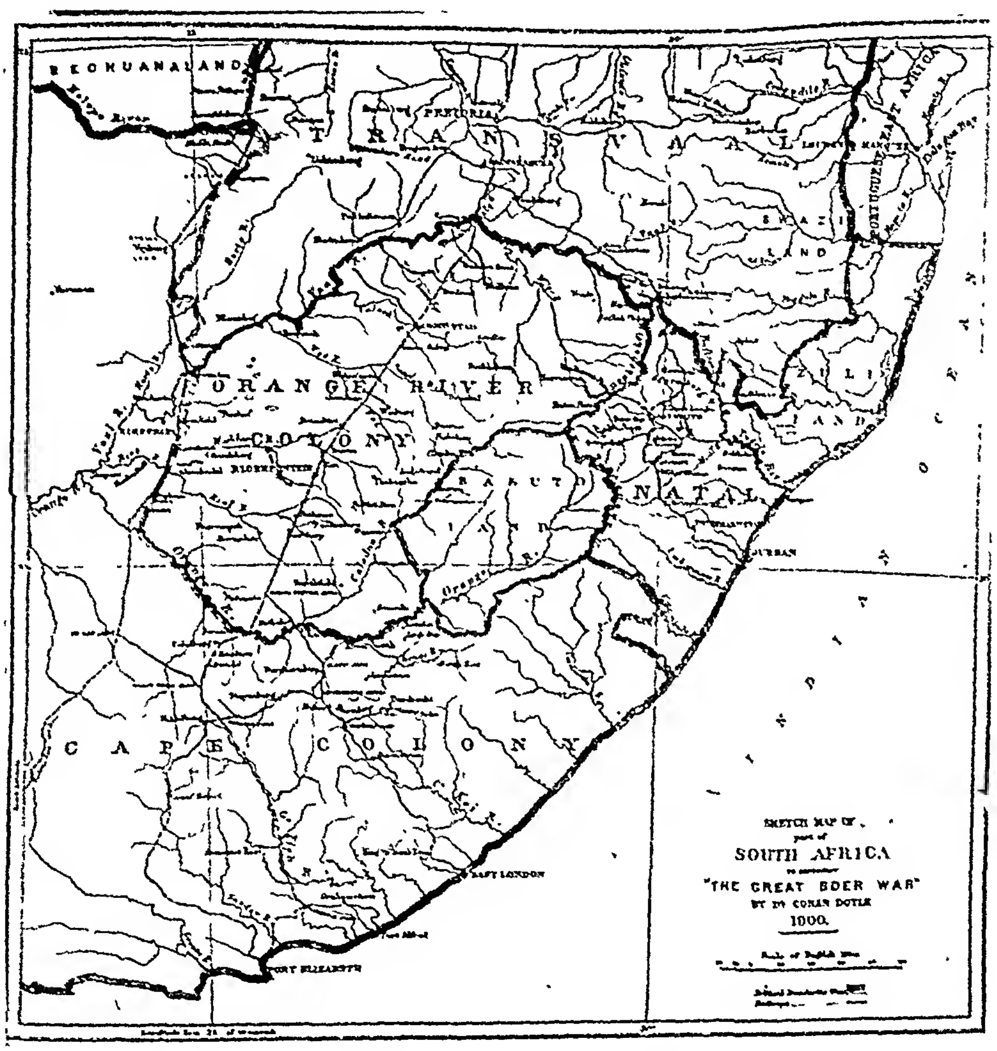

Fig. 14. Reproduced from Doyle.[11]

experience up the Nile he knew that it would be useless to take the specially fitted-up bicycle which had been used as a motor for a dynamo. Bruce confessed that he had no faith in manual aid for driving a dynamo and he could speak from experience because he was in the Nile campaign and with the temperature in the hut over 100 degrees this style of charging batteries left an impression on him that his relationship with a dynamo was extremely small. Consequently he had the batteries charged before he left Cairo. In addition, he took along the usual roentgen apparatus and a dynamo, trusting that some means might become available to drive it.

The destination of Lieutenant Bruce was Pietermaritzburg, which he reached without any mishap. He later had orders to proceed to Ladysmith, which he did on October 16, taking all apparatus with him. A portion of the Town Hall was used for the x-ray department. The first series of cases were very soon furnished from the battle of Elandslaagte. The number of cases from this battle which required examination was not very large. Few patients had to be examined for bullets, the majority of the wounded having bone injuries. This absence of imbedded bullets may be accounted for by the fact that the firing was at short range, and those bullets which did not pass through the parts caused severe injuries to the bones when these obstructed their course. All the bullets were successfully localized and subsequently extracted. Fortunately, in that work none of the bullets lodged in the pelvic region, as the Mauser bullet, being so small, proved very awkward to find in deep tissues.

During the period from October 30 to November 3, shells were continually dropping in the neighborhood of the hospital. Nevertheless, the work in the roentgen-ray room was carried on as usual. Great caution had to be used in roentgenographing the patients when shells were heard in the immediate vicinity, as they were sure to start, thinking the building would be hit. Exposures under these conditions had to be of the shortest (probably only ten or fifteen minutes instead of the usual twenty or thirty), necessitating long developments. They eventually arranged for a lookout to announce the firing of the gun, which did much to facilitate their work.

As it was apparent that considerably more work would have to be done, there became the problem of charging the batteries. Bruce knew that close to the Town Hall was situated a flour mill and he asked for permission to have the dynamo driven from the mill shafting. This worked remarkably well and charged the batteries most efficiently.

Among the wounded, some interesting cases were roentgenographed, showing the behavior of the expanding bullet used by the Boers. They showed the lead scattered about the injuries in all directions, the mantle remaining nearly intact. The number of cases actually recorded was 200, of which nearly one-half was roentgenographed. In addition, a vast number of cases under treatment were examined by the surgeons with the fluoroscopic screen. As in the Nile campaign, work with the screen was best done in the evening unless the roentgen department was so situated as to permit of darkening the room in the daytime.

In regard to the general results by the roentgen apparatus, all were unanimous in saying that it was of the greatest assistance, not only in locating bullets but also as an aid in the treatment of fractures generally.

The great demand for the increased use of the roentgen ray in army campaigns was best emphasized in this war in that each of the general hospitals had a complete outfit and many of the smaller ones had the necessary apparatus.

It is of historical interest to note that at the time of the Siege of Ladysmith, Winston Churchill[9] had landed at Durban and had made his way to Estcourt where he became a member of that group which attempted by means of an armoured train to pass through the enemy's lines. The

story of his capture by the Boers, his imprisonment and his subsequent escape is too well known for comment.

THE SPANISH-AMERICAN WAR—1898

In the Spanish-American War roentgen-ray apparatus was used to a limited extent due to the type of warfare and to the fact that the activities of the Medical Corps were consumed in caring for those ill with typhoid fever. However, the more important of the general hospitals and three hospital ships, namely the *Relief*, the *Missouri* and the *Bay State*, were supplied with roentgen-ray apparatus. The type of apparatus used in the hospitals was essentially that used in the previous wars, that is, coil apparatus and storage batteries, the more recently constructed static apparatus, this last being so heavy that its use was confined to fixed hospitals and hospital ships.[5]

WORLD WAR I

With the close of the Boer War and the signing of the treaty of peace following the Spanish-American War, there was a period in which the whole world seemed to be free of wars. During this time great strides were made in the manufacture of technical equipment of all kinds. An unprecedented era of invention and research developed, with advances in all fields. The progress of the science of roentgenology did not lag behind. The generating source was gradually emerging from the chrysalis stage of coil and batteries, and radical changes were made in tube designs.

Then came World War I, a war the magnitude of which, in comparison to the former small wars is most vividly expressed by the following now famous description by Winston Churchill:[8]

> The wars which had preceded World War I were the kind of warfare full of fascinating thrills. Nobody expected to be killed. Here and there in every regiment or battalion, half a dozen, a score, at the worst thirty or forty, would pay the forfeit; but to the great mass of those who took part in the little wars of Britain in those light-hearted days, this was only a sporting element in a splendid game. Most of us were fated to see a war where the hazards were reversed, where death was the general expectation and severe wounds were counted as lucky escapes, where whole brigades were shorn away under the steel flail of artillery and machine-guns, where the survivors of one tornado knew that they would certainly be consumed in the next or the next after that.

This was really war with all its grim tragedy.

It was not a coincidence that when the demand on medical skill at once became so enormous, the immeasurable importance of the roentgenologist should have sprung to the front. By this time the invention of the Coolidge tube had done away forever with the capriciousness of the gas tube, and in 1916 the introduction of the Potter-Bucky diaphragm had freed the roentgen images of their fogginess and indistinctness.[19] Fortunately, as a result of these two great discoveries, the American Expeditionary Force of World War I was supplied with the finest roentgen-ray equipment that the world had known up to that time.

Welch,[12] returning from the war front, in an address before the Johns Hopkins Hospital Medical Society on November 6, 1917, said that on and around the foreign battle fields there was an opportunity of using to the full all the recent medical discoveries, among them advances and improvements in the way of inoculations against disease, in sanitary matters, pure water and incineration, and in the use of the roentgen rays which he declared to be of incalculable advantage in conditions of war.

World War I had been in progress three years before the entrance of this country into the conflict and during these years the European countries continued to use the induction coil equipment, especially for their mobile war units. They also employed the gasoline engine driven dynamos or generators for their current supply, making use of either the engine of the truck that

carried the apparatus, or a separate engine. They continued with this type of exciting apparatus with the gas tube through World War I.

It may be of interest to note at this juncture that the first Coolidge tube which the French saw in operation was in the American Military Hospital No. 1 in 1917. Dr. Bèclére and his group of students made a special trip to the hospital, where I was stationed, one Sunday morning to view the tube in operation.

Previous to our entry into the war some of the more thoughtful members of these two societies, realizing the urgency and need not only for equipment but also for trained roentgenologists, since there was an inadequate supply of the latter, set about to remedy this defect. It is true that both the Army and the Navy had roentgen-ray equipment in their hospitals, and for some time before World War I all the Army medical officers were given limited practical courses of instruction with the roentgen apparatus then available. Upon the entry of this country into the war, with the sudden and rapid expansion of both the Army and the Navy, it was necessary to take these men who had had training in roentgenology and utilize them in other medical activities of the Army and Navy. Surgeon-General Gorgas recalled to active service Colonel Arthur C. Christie and acting on Colonel Christie's advice created a division of roentgenology of the Army Medical Corps. General Gorgas placed Colonel Christie in charge of this division and he in collaboration with a number of roentgenologists quickly organized medical centers in all parts of the country for the training of roentgenologists and technical assistants and repairmen. Many of the latter were promptly supplied by the manufacturers. At the same time he called into consultation the manufacturers, seeking to improve especially the portable type of apparatus which was necessary for the advance hospitals, and in collaboration with Dr. Coolidge there was soon evolved a small gasoline engine for the generation of electricity, this engine being reduced to the absolute minimum as regards the parts so that it would require the least amount of technical care. This, coupled with the transformer and the Coolidge tube, represented an enormous advance in the portable equipment; not only could it be used at the front line hospitals, but also as an auxiliary unit in the fixed hospitals.[7]

During the progress of the war there was introduced as a result of Major Shearer's efforts a bedside unit using the radiator type of Coolidge tube and this unit was extensively employed in the large stationary hospitals both at home and abroad.[13] There was also constructed a standard United States Army roentgen-ray table which is well known to all roentgenologists. It is of interest to note that at the time of the Armistice almost a thousand sets of roentgen-ray apparatus of various kinds had been sent abroad. The schools established for the instruction of roentgenologists began classes in July, 1917, very shortly after our entrance into the war, and by the end of December, 1917, over two hundred men had been trained to serve as roentgenologists. These men quickly supplemented the inadequate number at the beginning of hostilities. Not only was the roentgen ray used in the localization and removal of projectiles, shell fragments and bullets and other foreign bodies, but also for the diagnosis and control of fractures and dislocations. Furthermore, for the first time in warfare the roentgen ray played an important rôle in the early diagnosis of gas gangrene, one of the most devastating and crippling infections encountered on the battle fields of France.

The Committee for the Organization of Schools and the Teaching of Roentgenology sent an official report to Surgeon General Gorgas in which the suggestion was made that in addition to a careful clinical examination of the chest a roentgenological examination of every recruit for the Army or Navy should be made in order to determine his fitness for the service. Unfortunately, this recommenda-

tion was not accepted. Twenty-five years later, in World War II, we saw the fruition of this official recommendation.

We all owe a great debt of gratitude to those far sighted individuals who, recognizing the needs of the Army and Navy, set about the establishment of the schools for the training of roentgenologists. Not only did this contribute toward better medical and surgical care of the soldiers and sailors both overseas and at home but undoubtedly that pioneer work placed roentgenology on the high road which you and I travel today.

WORLD WAR II

The wheel has turned full cycle. After the twenty-five years which have elapsed since World War I, it has again become necessary to mobilize our forces in a global war. We find ourselves fighting at one and the same time over the face of the earth in the same places where these little wars, which have just been described, and

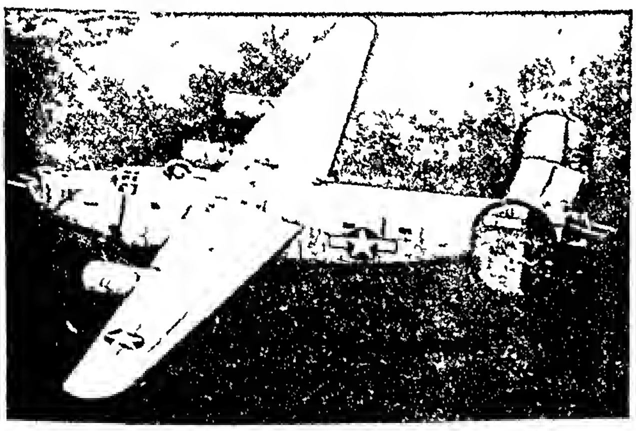

Fig. 15. Use of airplane in transporting roentgen-ray equipment in World War II.

World War I were previously waged. Into these areas there has been carried by modern means (Fig. 15) roentgen-ray equipment (Fig. 16–23)* as up-to-date as the vehicles in which it has been transported—far removed from the coil, batteries and Crookes tubes that saw service in the previous campaigns in these countries.

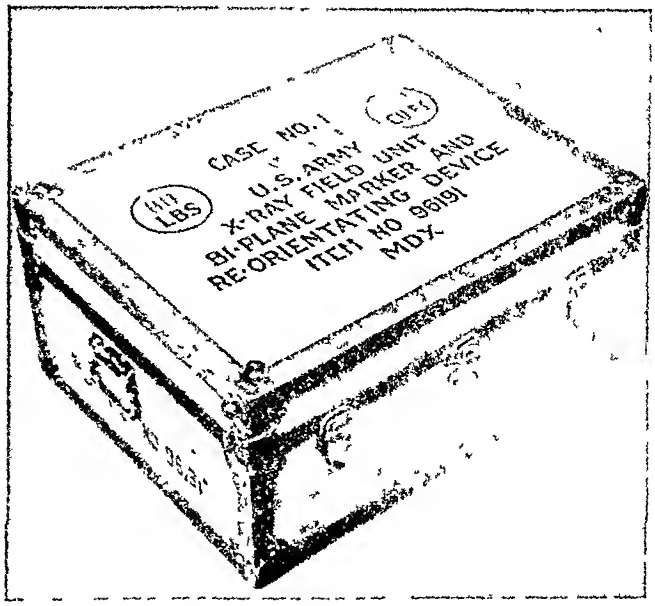

Fig. 16. Figures 16 to 23 show some of the roentgen-ray equipment used in World War II. These illustrations were kindly furnished by Colonel A. A. de Lorimier, Army School of Roentgenology, Memphis, Tennessee.

Manges[18] made a prophetic statement when he said, "In the event of another war involving our country, it is entirely probable that roentgenologists other than regular Army Officers would be needed; but it is also probable that special instruction in military roentgenology, if needed, would be given by regular Army Officers rather than by newly commissioned or reserve officers, as was done in 1917 and 1918, during the World War." Certainly Colonel de Lorimier and his corps of officers have rendered inestimable service to their country in the present war in mobilizing not only the equipment but the schools of instruction and training of personnel to meet the present emergency and he has from time to time presented to these two societies the progress of his efforts.

The advance of roentgenology over the intervening years has been such that its use in the examination of the chests of draftees is no longer debatable. We have seen millions of men inducted into the armed forces whose physical fitness was primarily established by the roentgen examination of the chest with the new units developed for mass survey.

* For additional illustrations of the roentgen-ray equipment used in World War II, see the article in this issue of the Journal by A. A. de Lorimier and Maxwell Dauer entitled "The Army Roentgen-Ray Equipment Problem."

Fig. 17

Since the mobilization and the quality of the roentgen-ray equipment in its medical usages in the present war is known to some extent to all of us, it was thought that it would be of interest to discuss its employment in another field which has become so vitally important because of the nature of

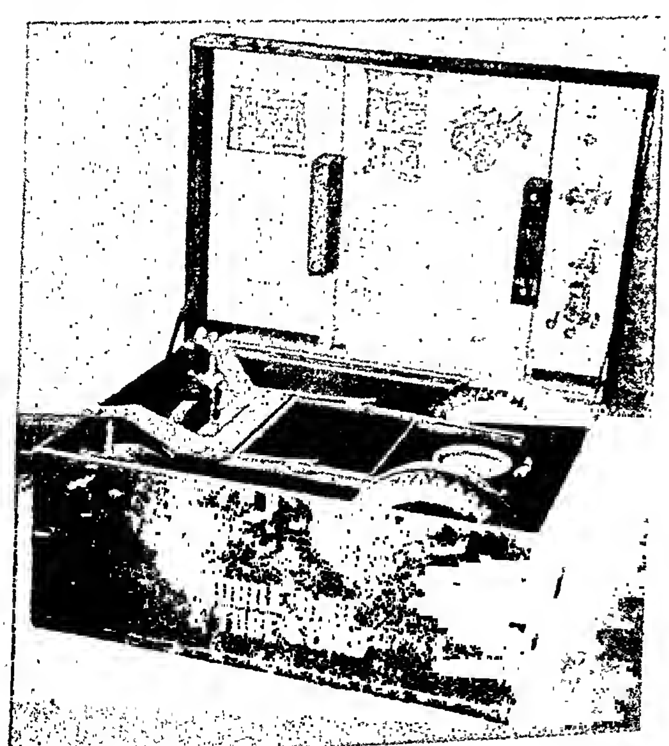

Fig. 18

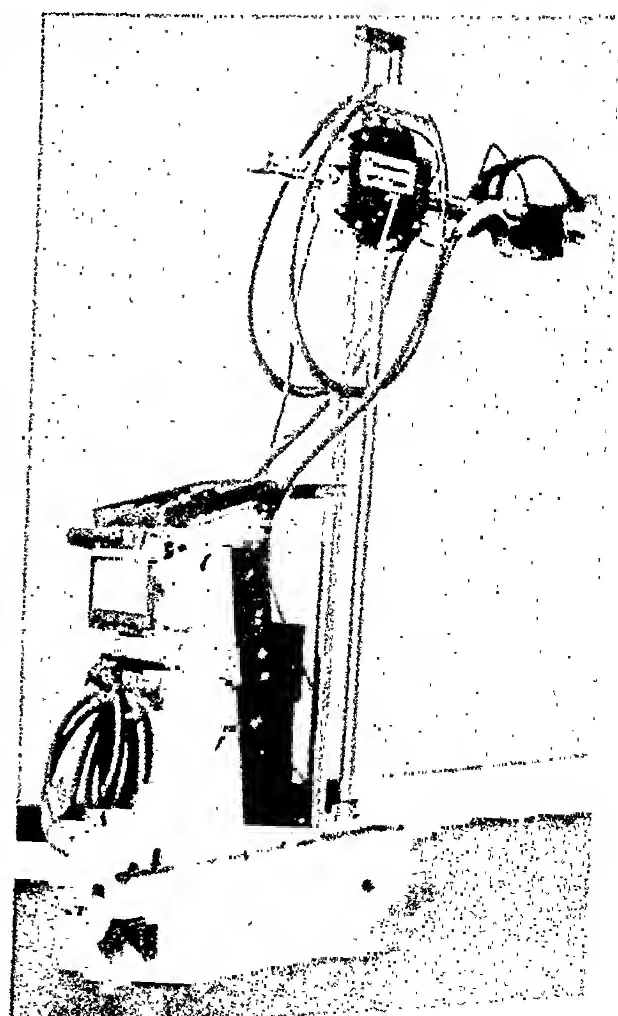

Fig. 19

the war we are waging. This field is the industrial application of the roentgen

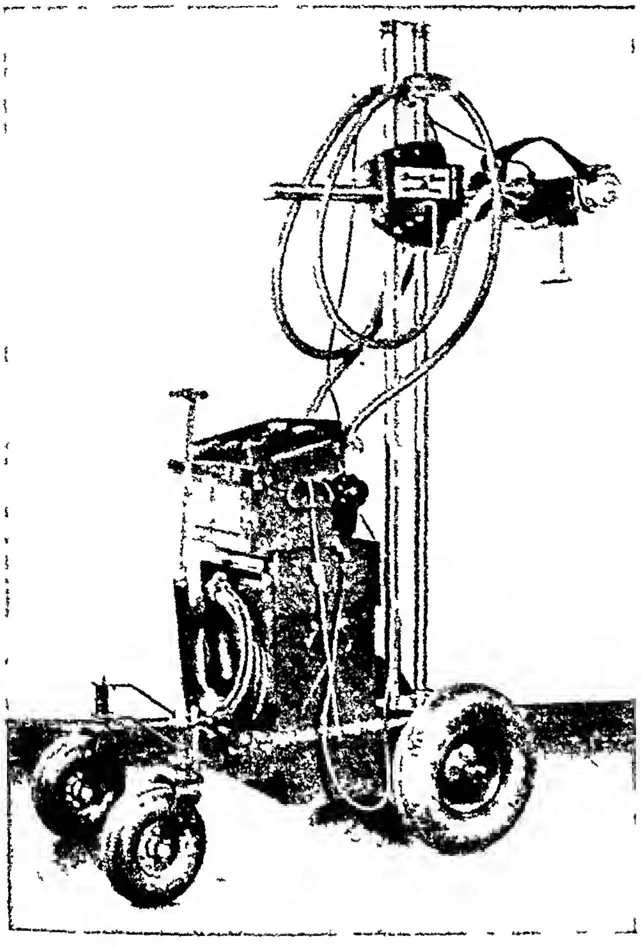

Fig. 20

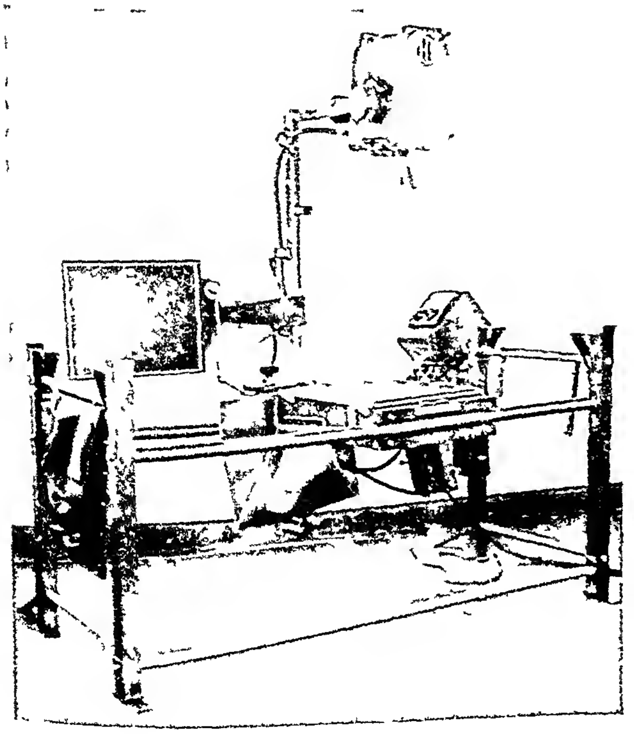

Fig. 21

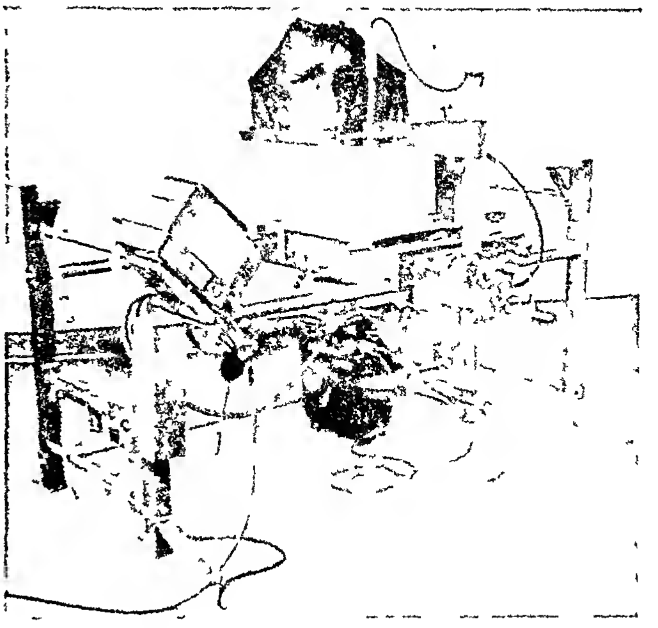

Fig. 22

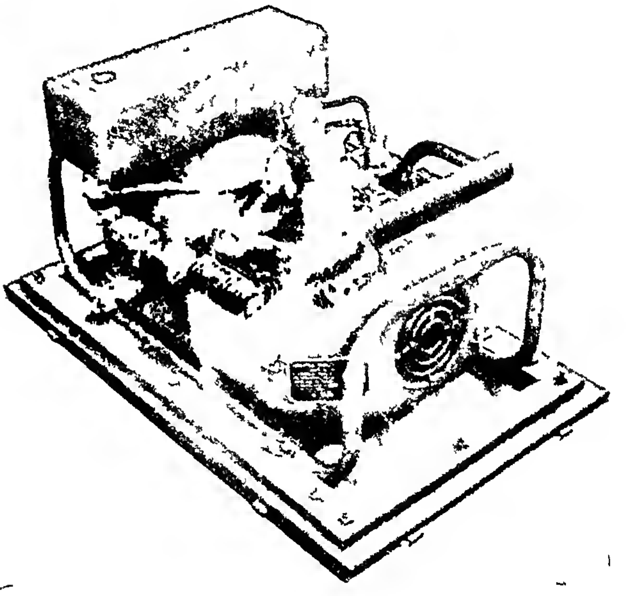

Fig. 23

rays. By testing the structures of the metals and the various materials used in military equipment, a service is rendered which brings the roentgen rays into the domain of preventive medicine through saving of countless lives which might otherwise have been lost as a result of defects in the essential parts of such equipment.

Historically, we find that the use of the roentgen ray in industry* is, like all phases

* We are indebted to John L. Bach and the General Electric X-Ray Corporation for many of the historical details of the use of roentgen rays in industry.

of sound scientific progress, the story of early recognition and then a long period of development which resulted in the efficient, shockproof, high power apparatus which is in use today.

Practical application of the roentgen ray in industry, while recognized early as having great possibilities, did not become an actuality until the advent of more powerful apparatus. This started in the United States in 1922 when roentgen-ray transformers, controls and tubes reached a degree of perfection which permitted the use of very high voltages. Continued technical improvement led to gradually increasing voltages until now roentgen equipment which operates at one to two million volts, with complete safety and precise control, is available.

One of the most important advances in roentgen-ray apparatus came with the development by Coolidge of the principle of immersing the roentgen tube and transformer in an hermetically sealed and grounded tank. This provided shockproof and climate proof operation, eliminated the need for high voltage cables, made possible unusually compact design and greatly increased the range of service for industrial roentgen units.

The first application of the roentgen ray in industrial roentgenography in this country was made at the Watertown Arsenal. It was here that much of the real pioneering work in the employment of roentgen rays for non-medical purposes was carried out and much was accomplished especially in demonstrating flaws in metal structures and determining their effects upon the ensemble of the structure.

The aluminum industry next—about 1927—adopted roentgen-ray equipment for a study of their products. Here was a preliminary step of most vital importance to the present program of war material production because roentgen rays have played an indispensable rôle in the development of aircraft. It was recognized early that all parts going into aircraft should be as light as possible and still provide the necessary strength. Aluminum, therefore, found a ready acceptance. But even with the light weight material, engine parts and structural members had to be designed for maximum strength with minimum weight—a job in which the roentgen ray served as an invaluable guide to results that can well be considered truly remarkable.

Later the roentgen ray entered another field. Leading manufacturers of high-pressure boilers wanted to eliminate riveted structures and adopt welding as a standard construction method. Welding up to that time had been considered simply as a convenient method of sticking two pieces of metal together. Little thought was given to the metallurgical considerations involved; nor was much time spent wondering if it would be possible for a welding operator to place weld metal free of the defects that would make welding practically useless in the boiler industry. Progressive, far-seeing manufacturers changed all that. They used the roentgen ray to examine completed welds, learned to diagnose defects and their causes and used roentgenograms to point out these defects, and the mistakes that caused them, to welding operators. The results were better welding and welds strong enough to meet the requirements for high-pressure vessels of many types. In some cases, modern practice required complete roentgen examination of welded seams and in others roentgen-ray inspection of weld samples provided a periodic check on the quality of work being done by the individual operator.

Welding has always carried with it one great disadvantage, in that the heat used for welding changed the nature of the parent metal. It has long been known that a weld, properly made, is stronger than the metal around it. Figure 24 shows one reason why this is so. Here we have a perfect weld but the armor plate has lost its tensile strength and cracked. At the top of the figure is a roentgenogram of the whole plate, in the center a roentgenogram of the

specimen after it was cut out and at the bottom a photographed section, four times enlarged, of the piece itself. Modern techniques have eliminated this source of failure.

So it is from the pioneer work done in the application of roentgen rays, first to heavy castings at the Watertown Arsenal and then to light metal castings by the aluminum industry and lastly to welding, that the tremendous benefits are being reaped in the present war production program.

A few examples of the applications of the roentgen ray in a variety of industries may prove of interest. In the Navy, roentgen-ray examination of the castings that go into turbines is an accepted routine; the welds and castings which go into high-pressure steam system's aboard ship are also roentgenographed, as are weldments in gun mounts. Army gun mounts and carriages too require roentgen examination, as do certain parts of tanks and other heavy armament materials.

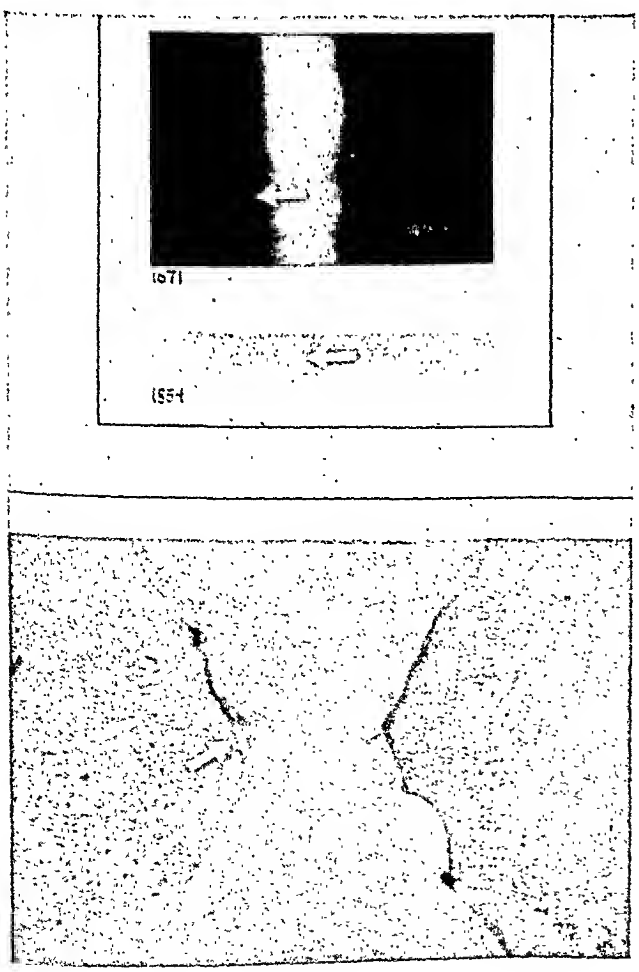

Fig. 24

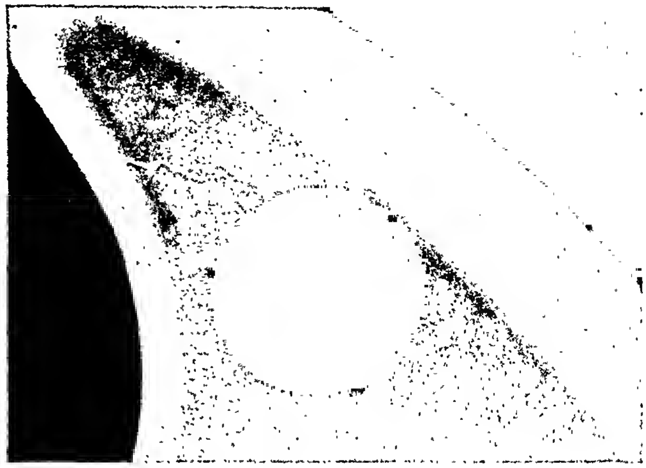

Fig. 25

In the aircraft industry, many of the parts are so important that every one that goes into the airplanes is inspected by the roentgen ray.

In the examination of the various kinds and thicknesses of metal, different types of industrial roentgen units are used, operating at voltages ranging from 60,000 to a million volts and just recently a unit operating at two million volts has been made available. The production of these high voltage units has played an important part in the speeding up of vital war production and has cut innumerable hours and days off inspection time. In some cases it has reduced inspection time of a single large casting weighing as much as 50 tons from five days to five hours. These high voltage units are also important in increasing enormously the number of parts which can be examined.

In addition to saving the lives of our fighting men by the elimination of defective vital parts, a great amount of time and money is saved because the castings are examined in the rough before the final polishing is done. Thus if a defect is found, that part is discarded without the waste of further effort.

Obviously, all these roentgen demonstrations of flaws and defects in the densest metals are of inestimable value from the point of view of an enormously speeded up war program. However, it would be of a

Fig. 26

still greater importance if means could be found to eliminate the cause of these flaws and defects at the source and thus develop methods for producing unprecedented numbers of perfect parts. In this battle of production which we have waged and won, with resultant saving of thousands of lives of our soldiers, the roentgen ray has again been our most important weapon. Only a very few examples can be shown at this time, but they illustrate how this was done. Figure 25 is a roentgenogram of an aircraft part cast of "duralumin." The bright line which traces an uneven course across the center of the film is copper which has frozen out of the alloy due to strain which occurred when the part cooled and contracted in the mold. By studying the flaw with the roentgen ray it was possible to map out the nature and direction of the strain, and find its cause, after which a simple change in the mold eliminated the trouble. Figure 26 illustrates the adaptation of an old method. This is a pre-war "diecasting" showing many flaws and holes beneath the surface. The method gives fast production but because of its faulty products it was used only for such things as door handles for automobiles. Figure 27 shows some modern diecastings. These are vital parts of military aircraft. Before the war these parts were machined out individually and it was believed that no other method could produce the needed precision and perfection. Total production, however, amounted to only a few hundred per year and thousands were needed at once. Experimental diecastings were made and their flaws studied by the roentgen ray. When the nature of these flaws was brought to light and it was shown that they always occurred in the same location, it was possible to make changes in the die and the technique which completely eliminated the flaws and made possible the production of perfect parts in any number desired.

Sand casting is a process of great antiquity, which up to the time of the war had not undergone any fundamental change. In sand casting, first a model, called a "pattern," is made of wood or wax in the shape of the desired piece. This pattern is imbedded in a box of sea sand to which has been added an organic binder such as molasses and an inorganic binder such as clay. Means are provided for getting the pattern out after the sand has set firmly around it. Molten metal is then

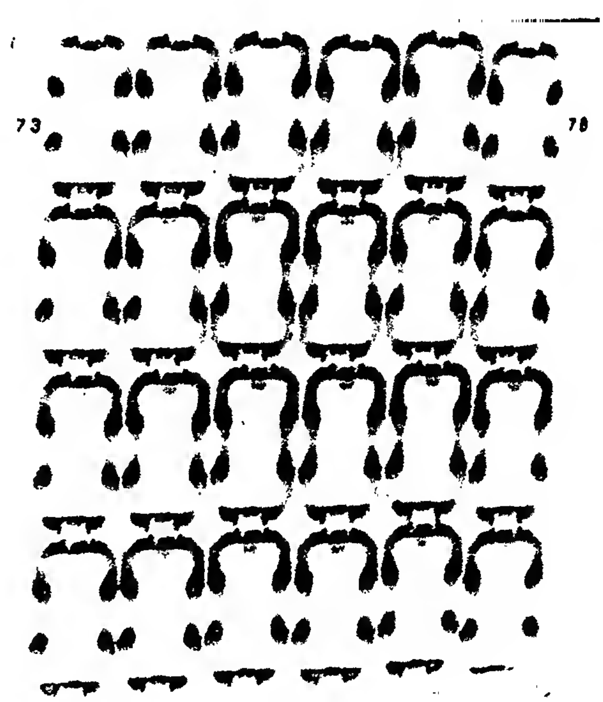

Fig. 27

poured in through a hole and cools in the shape of the original model. The process has always been used for producing the heavy parts of machinery and for such things as the motor blocks of automobiles, but in its ordinary form it is a process from which no great amount of precision can be expected. In addition, the surface of the casting is always rough and uneven and the method unsuitable for the production of parts having fine detail or deep grooves in their surfaces. All of this had to be changed, for sand casting is a fast method of production. It was changed. Experimental castings made with roentgen-ray control quickly showed that the porosity, gas pockets in the metal and the coarse grain structure of the metal itself could be eliminated, giving strength, and that the metal could then be made to fill in even the most intricate surface detail. Figure 28

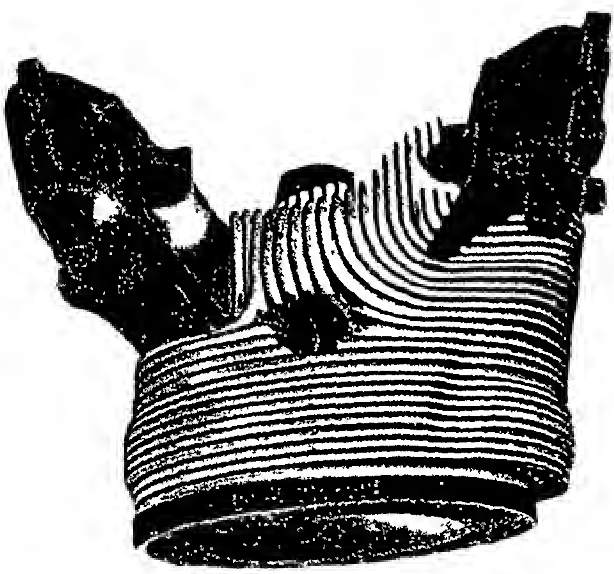

Fig. 28. Illustration courtesy of Don McCutcheon and the Ford Motor Company. By permission of the United States Army.

shows an aircraft cylinder head produced by present day sand casting methods after roentgen-ray research had eliminated the causes of trouble. Figure 29 illustrates a sand casting for an aircraft motor, in which at one point two waves of molten metal flowed together, in the casting process, trapping a layer of oxide between them.

Fig. 29

The result was an occult flaw which allowed the part to pass all standard tests, but later, after it had been heated up a number of times, could open, and result in the sudden destruction of the motor. This flaw occurred at a point which could not be depicted by ordinary roentgen techniques and a special method, which we are not permitted to discuss at this time, had to be devised. Once it was discovered, its elimination was easy.

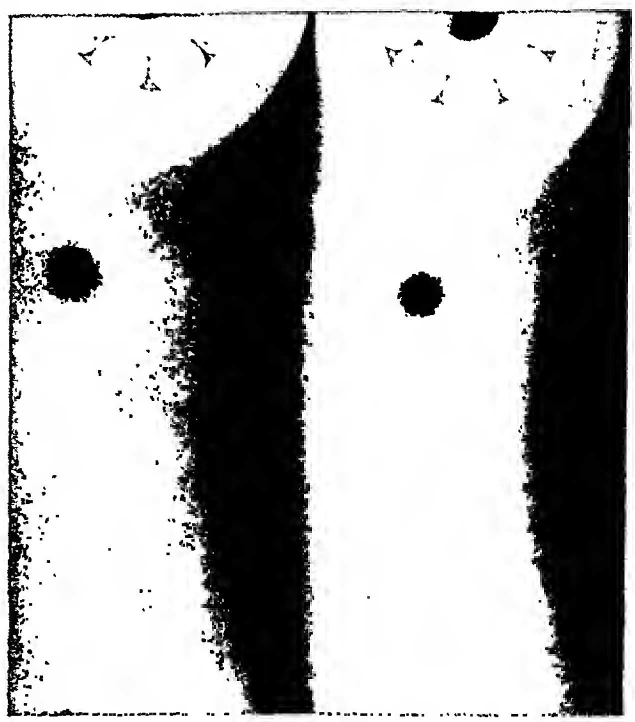

Fig. 30

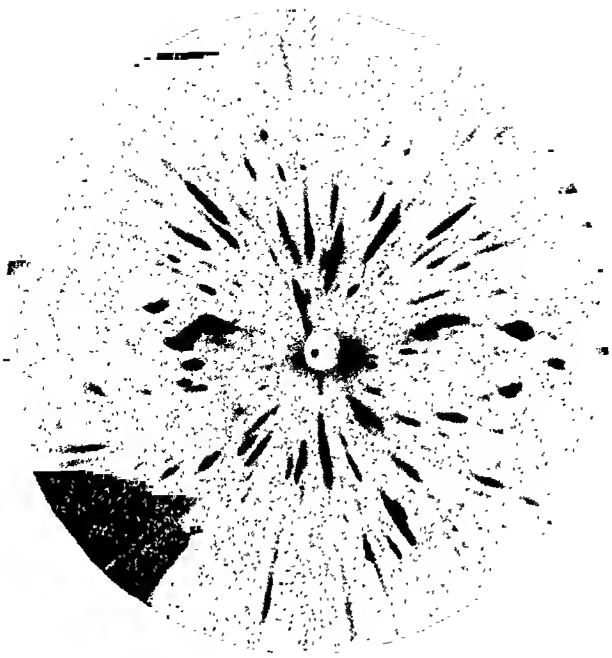

Fig. 31

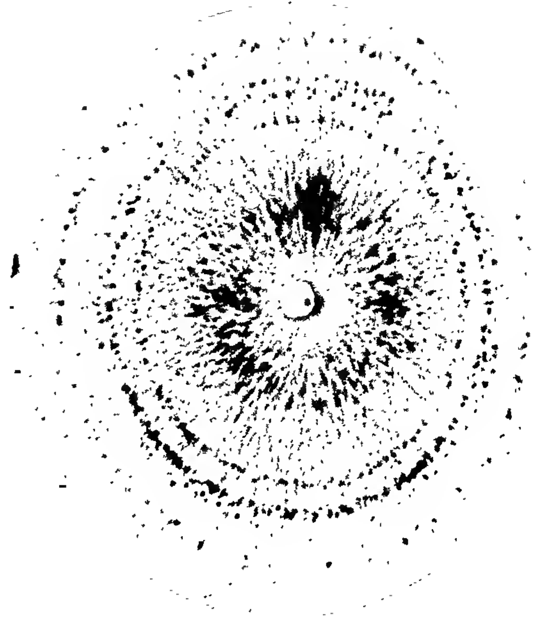

Fig. 32

Still, roentgenography is not the whole story in connection with industrial investigations and structural research. For some time now it has been necessary to lean heavily upon another *roentgen-ray* procedure which is based on diffraction. Originally diffraction studies were the special field of theoretical scientists, but before 1930 a patent had been granted to an American for the production of a new kind of rolled steel, far better and stronger than anything which had gone before, and this patent, together with the entire process was the product of roentgen-ray diffraction experiments.

The practical side of diffraction in this war is shown in the next few illustrations. Figure 30 shows a roentgenogram of a vital part of one of our Navy planes. From all possible roentgenographic evidence, this part is perfect. This roentgenogram was made early in the war and the piece shown had been made by the best forging process then known. However, planes equipped with this part lost their wings while in mid-air. When this problem came to the research laboratory, it was soon discovered what was wrong. By the diffraction method it was shown that the forging process had developed a crystal structure which was weak and fragile (Fig. 31). The *forging* process was then improved and Figure 32 shows that after the process was changed the part now has sufficient strength. The re-arrangement of the molecules can be seen.

A field no less important in which roentgen-ray diffraction has been put to use is the examination of quartz crystals which are so vital in all radio intercommunicating systems. There is enough quartz of proper quality in both North and South America but through glacial

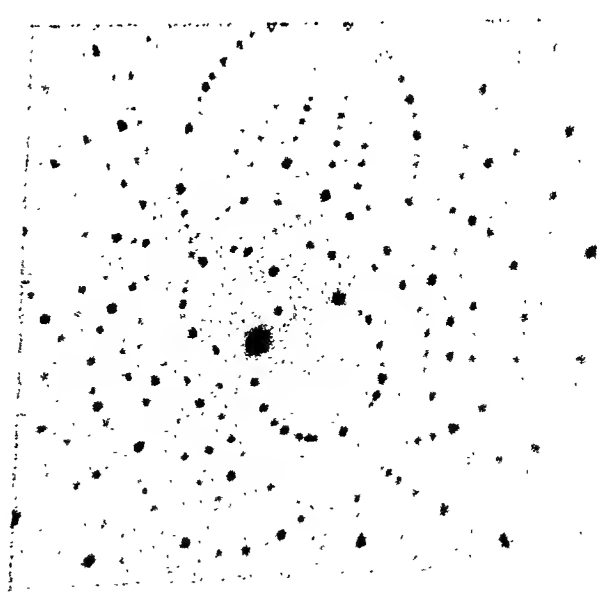

Fig. 33

action and other geologic catastrophies, these crystals have been ground down into shapeless masses and it was thought impossible to cut usable crystals from them. However Figure 33 illustrates how it was done. The rough piece of quartz was subjected to diffraction studies; a pattern such as this one showing the internal crystal structure tells immediately where the crystal axes lie and shows how to rotate the crystal to get the desired alignment. The crude piece of quartz is then cut into slabs at the proper angle with respect to its crystal structure and these slabs are then ground to proper precision for use.

These illustrate a few of the uses to which the roentgen ray has been put in industry in this global war. Time does not permit me to discuss the enormous aid which the roentgen ray has proved in such problems as the manufacture of synthetic rubber, silk substitutes, plastics, metal fabrication and a host of other problems.

Without soaring aspiration and without daring deed there is no science, no knowledge of nature. The conquest of a new region of knowledge resembles in many respects the occupation of virgin territory. First come the roadmakers, who unite a number of isolated points; then come the bridge-makers, who span many a yawning chasm; and last come the temporary shelters, which must ultimately be replaced by statelier buildings on deeper foundations and composed of more durable materials.[15a]

When once peace is established it is to be hoped that all of us will take the more durable materials that have emerged from the scientific efforts in these tragic years and bend them toward the uses for which they were primarily intended, namely for the betterment of mankind.

REFERENCES

1. Abbott, Francis C. Surgery in the Greco-Turkish War. *Lancet*, 1899, *1*, 80–83; 152–156. The roentgen rays (with Mr. Fox Symons, by whom most of the skiagrams were taken).
2. Alvaro, Guiseppa. I vantaggi practici della scoperta di Röntgen in chirurgia. *Giornale medico del regio esercito*, 1896, *44*, 385–394.
3. Battersby, J. The present position of the roentgen rays in military surgery. *Arch. Roentg. Ray*, Feb., 1899, *3*, 74–80.
4. Beevor, W. C. The working of the roentgen ray in warfare. *J. Roy. United Service Institution*, London, 1898, *42*, 1152–1170.
5. Borden, W. C. The Use of the Röntgen Ray by the Medical Department of the United States Army in the War with Spain (1898). Government Printing Office, Washington, 1900.
6. Bruce, F. Experiences of x ray work during the Siege of Ladysmith. *Arch. Roentg. Ray*, March, 1901, *5*, 69–74.
7. Christie, A. C. Mobile roentgen ray apparatus. Am. J. Roentgenol., 1919, *6*, 358–367.
8. Churchill, Winston S. A Roving Commission: My Early Life. Charles Scribner's Sons, New York, 1930, p. 180.
9. *Idem.*, p. 243.
10. Churchill, Winston. The River War: An Account of the Reconquest of the Soudan. Charles Scribner's Sons, New York, 1933.
11. Doyle, A. Conan. The Great Boer War. McClure, Phillips & Co., New York, 1900.
12. Editorial. The war call. Am. J. Roentgenol., 1917, *4*, 253–254.
13. Editorial. Professor Shearer's services to the Army. Am. J. Roentgenol., 1922, *9*, 523–524.
14. Encyclopaedia Britannica. Fourteenth edition. Vol. 13, p. 368. Encyclopaedia Britannica, Inc., Chicago.
15. Encyclopaedia Britannica. Fourteenth edition. Vol. 22, p. 240. Encyclopaedia Britannica, Inc., Chicago.
15a. Gomperz, Theodor. Greek Thinkers. Vol. I. Translated by Laurie Magnus. John Murray, London, 1920, p. 295.
16. Hutchinson, H. D. The Campaign in Tirah, 1897–1898; An account of the expedition against the Orakzais and Afridis under General Sir William Lockhart. Macmillan & Co., Ltd., London, 1898.
17. Küttner, H. Ueber die Bedeutung der Röntstrahlen für die Kriegschirurgie; nach Erfahrungen im griechisch-türkischen Krieg 1897. *Beitr. z. klin. Chir.*, 1898, *20*, 167–230.
18. Manges, W. F. Military roentgenology. In: The Science of Radiology. Otto Glasser, Editor. Charles C Thomas, Springfield, Illinois, 1933, pp. 187–197.
19. Potter, H. E. Diaphragming roentgen rays; studies and experiments. Am. J. Roentgenol., 1916, *3*, 142–145.
20. Shadwell, L. J. Lockhart's advance through Tirah. W. Thacker & Co., London, 1898.
21. Warburton, Robert. Eighteen Years in the Khyber, 1879–1898. John Murray, London, 1900, p. 290.

ADDITIONAL REFERENCES

ALFORD, HENRY S. L., and SWORD, W. D. The Egyptian Soudan: Its Loss and Recovery. Macmillan and Co., Ltd., 1898.

ATTERIDGE, A. HILLIARD. Towards Khartoum: The Story of the Soudan War of 1896. A. D. Innes and Co., London, 1897.

BARCLAY, A. E. Preliminary note on a new method of bullet extraction. *Arch. Radiol. & Electroth.*, 1915–1916, *20*, 359–368.

BOWEN, D. R. Localization of foreign bodies. AM. J. ROENTGENOL., 1918, *5*, 59–74.

CLEVELAND, A. J. Accurate localisation of foreign bodies in tissues by x rays. *Arch. Roentg. Ray*, 1914–1915, *19*, 290–293.

COLE, L. G. Address by the president. AM. J. ROENTGENOL., 1918, *5*, 363–368.

DUNCAN, W. A. X-ray equipment and work in the Army at the present time. AM. J. ROENTGENOL., 1914, *1*, 268–275.

EDITORIAL. Roentgen rays in war times. AM. J. ROENTGENOL., 1917, *4*, 254–257.

HAMPSON, W. Localising simply and immediately. *Arch. Roentg. Ray*, 1914–1915, *19*, 203–205.

HERNAMAN-JOHNSON, F. Simple and rapid method of localising bullets. *Arch. Roentg. Ray*, 1914–1915, *19*, 247–248.

HERNAMAN-JOHNSON, F. Localisation of bullets. *Arch. Roentg. Ray*, 1914–1915, *19*, 305–306.

HOLDICH, T. HUNGERFORD. The Indian Borderland, 1890–1900. Methuen and Co., London, 1901.

HOLLAND, C. T. On the x-ray work at the First Western Base Hospital. *Arch. Roentg. Ray*, 1914–1915, *19*, 307–316.

MORGAN, J. D. Some examples of bone injuries caused by bullets, shell fragments, and shrapnel. *Arch. Radiol. & Electroth.*, 1916–1917, *21*, 41–49.

MORISON, J. M. W. Gas in the tissues. *Arch. Radiol. & Electroth.*, 1915–1916, *20*, 222–231.

PIRIE, A. H. Organization of x-ray department of a general hospital in France. *Arch. Radiol. & Electroth.*, 1915–1916, *20*, 332–335.

ROYLE, CHARLES. The Egyptian Campaigns, 1882 to 1885. New and revised edition, continued to December, 1899. Hurst and Blackett, Ltd., London, 1900.

SAVILL, AGNES. Some notes on the x-ray department of the Scottish Women's Hospital, Royaumont, France. *Arch. Radiol. & Electroth.*, 1915–1916, *20*, 401–410.

SAVILL, AGNES. X-ray appearances in gas gangrene. *Arch. Radiol. & Electroth.*, 1916–1917, *21*, 201–212.

SNOOK, H. C. Development of roentgenology. AM. J. ROENTGENOL., 1917, *4*, 337–342.

STEEVENS. G. W. With Kitchener to Khartum. Dodd, Mead & Company, New York, 1898.

STRAW, A. G. Use of x rays in the great war, with a new method for location of foreign bodies. *Arch. Radiol. & Electroth.*, 1916–1917, *21*, 392–395.

VILVANDRÉ, G. A few radiograms to illustrate the velocity of the rifle bullet as the determining factor in the extent of an injury. *Arch. Radiol. & Electroth.*, 1915–1916, *20*, 192–197.

VILVANDRÉ, G. Radiography in gun-shot wounds of the skull. *Arch. Radiol. & Electroth.*, 1915–1916, *20*, 306–313.

VILVANDRÉ, G., and MORGAN, J. D. Movements of foreign bodies in the brain. *Arch. Radiol. & Electroth.*, 1916–1917, *21*, 22–27.

VILVANDRÉ, G. Radiography in gunshot wounds of the thigh. *Arch. Radiol. & Electroth.*, 1916–1917, *21*, 140–148.

WEIGALL, ARTHUR E. P. BROME. A History of Events in Egypt from 1798 to 1914. Charles Scribner's Sons, New York, 1915.

WILKINS, W. A. The localization of foreign bodies. AM. J. ROENTGENOL., 1917, *4*, 343–350.

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THE ARMY ROENTGEN-RAY EQUIPMENT PROBLEM

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INTRODUCTION

With the recent world conflict at an end, there is a natural tendency to consider new avenues of interest; to look ahead and to forget the past. "There will be no more wars"—some may say. However, any army must not rest so complacently. Others, too, are thinking to the contrary and considering the distant future, when war may break out again. For such thinking, it seems practical to take some inventory of recent plannings and experiences and to record suggestions which might be of value in case another conflict is forced upon us.

There has been a marked change in the concept of roentgenological service requirements during mobilization and conflict; considering the viewpoints prior to the commencement of this last conflict, the provisions during the earlier months of it, and the activities of the last few years.

In particular, the demands for roentgenography were much more extensive than anticipated, either by personnel in the Army or by the roentgen-ray film industry.** Roentgenography has been required prior to entrance into the Service; it was extensively demanded with each hospitalization, and it was demanded even in the most forward installations where the original plannings had considered merely the use of roentgenoscopy.

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** During the last several years of the conflict, it was necessary to ration and to limit the supply of films to the civilian profession. All film manufacturers were operating at maximum capacities; still many doctors and many civilian clinics suffered roentgenographic restrictions. The Army required approximately half of all film production.

PRELIMINARY PLANNINGS

It was clearly anticipated that this conflict would be fast moving; that fronts would be moved rapidly, ahead or to the rear. Therefore, it was considered impractical to depend upon the use of any roentgen apparatus at the most forward medical installations. The third echelon concerned with the care of battle casualties was the farthest forward installation at which roentgen-ray equipment and services were provided (i.e., the motorized Evacuation Hospital, or the forward elements of the Field Hospital). It was realized that the equipment should be of a design permitting easy assembly and disassembly, together with simplicity of operation and maintenance; ruggedness and dependability for all military requirements.

Each item was designed as two or more component units. Each component unit could be packed separately, with bulk and weight limited to that which could be carried by two men. There was set, as a goal, a weight limit of 200 pounds, for any one component (packed). Detachable small parts were avoided. Versatile adaptations were provided, for it was believed important that each item should be serviceable for any and all types of hospital installations. Specific types of equipment for one or another echelon seemed impractical. It was realized that the handling of this equipment should be largely reflex, and that it should not be necessary for the operator to deliberate and study in detail the sequence of operation of the controls. In particular, it was believed important that equipment utilized in the forward echelons should be familiar also to the personnel serving in the rear who might sud-

denly be moved to the front. In this manner, the efficiency of transfer of personnel to other areas could be accomplished expeditiously with a minimum period of time required for adjustment to a fluid combat situation.

It was thought that roentgenoscopy should be most important; that otherwise there should be provision for a rapid method of foreign body localization and provision for roentgen therapy at least to the extent of handling infections and dermatoses. These believed-to-be essential fundamentals were provided with the roentgen-ray machine unit and the field table combination. Roentgenoscopy could be accomplished with the patient lying on the litter on which he had been placed when removed from the combat area. It could be accomplished with the patient recumbent, sitting, or standing. Roentgenography could be performed similarly. In connection with the adaptations for roentgenography, it was the original plan that films and processing equipment, together with chemicals pertaining thereto, would be provided only for the fixed type of hospitals. Foreign body localization, with respect both to the horizontal and vertical planes, could be accomplished with this equipment, within fifteen to sixty seconds and without the need for films or chemicals.[1]

The roentgen-ray machine was ordinarily utilized in connection with the field table. Depending upon the demands of the roentgenologic situation and to provide for use of the unit for ward work, a mobile chassis was designed. The earlier mobile chassis was equipped with small caster-type wheels for supporting the base. With the increase in the range of roentgenographic activities over all sorts of rough ground and improvised hospital buildings, this chassis was modified and equipped with large pneumatic rubber tires.

A special tent was developed having lightproof characteristics. Double purpose features were provided for it, also. The front curtains of it could be arranged to permit easy ingress or egress, such as would be required for roentgenoscopy. Otherwise, the curtains could be adjusted to provide for a labyrinth arrangement, thereby rendering it practical for the processing of films. The supporting structure of the tent was such that it was possible to set it up in any area that might be available. It could be used inside a room, an underground tunnel, inside a larger hospital tent, or set up by itself on the outside.

A combination film dryer and loading bin was also developed. It was designed in two sections in order to permit easy handling. The item was so arranged that it was possible to use it with the smallest type of hospital, and with multiples of the item, it was still practical for the largest installations that might be established.

In connection with the requirements for roentgenography, there was provided a film processing unit designed in accordance with the basic principle of minimum weight and flexibility of installation. This item consisted of a master chemical section and an auxiliary wash section. Each of these contained a tank and a pedestal. In the case of the master chemical section, the tank permitted the use of insert tanks, the size of which depended upon the type of hospital installation with which it was used. Its pedestal section served to circulate water from the main tank into the heating and or cooling compartment (the elements of which were thermostatically controlled). The auxiliary wash section served to expand the processing accommodations. In appearance, it was similar to the master chemical section and had the same physical dimensions and capacity. However, its pedestal unit did not contain the components for water circulation, refrigeration, and/or heating. Water connections with these items could be made to a common [illegible] water supply or continuous circulation of a bucket supply of water was possible.

A specially designed [illegible] generator was provided in order to [illegible] a dependable source of [illegible] phase, alternating current. The [illegible] type of commercial generator, [illegible]

below 5 kw. was not suitable for the roentgen-ray machine itself. Distortions in wave form, line surges and inefficient governor control were some of the common shortcomings. Conventional generators were not designed to handle the sudden fluctuations of load, such as produced by energization of the apparatus; having sudden fluctuations of load and utilizing only half the wave (i.e., except for the smaller loads concerned with heating of the filament). The generator that was finally provided was the result of a careful analysis* of the requirements of the roentgen-ray machine; it possessed the characteristics necessary to minimize tube and cable failures.

These were the initial problems; problems such as those previously described.[2] Conventional commercial equipment was to be supplied to the installations located in the Zone of Interior.

SHORTCOMINGS WITH RESPECT TO MATERIALS

During the early phases of construction, materials of all sorts were available. Aluminum and lightweight alloys were used extensively, and thereby weights were held at a minimum. Within the first year of large scale construction, shortages of the proper types of material produced a very definite problem. The Medical Department was no longer allocated the use of aluminum. As a consequence, re-toolings were required of the manufacturers and, in some instances, changes in design were necessary. Equally disturbing was the fact that weights were increased (several items which previously weighed below the 200 pound limit were increased 25 to 30 per cent in weight).

At the height of the manufacturers' production schedule, many important parts became highly critical; at times, almost unobtainable. This applied particularly to the electrical components: meters, special switches and relays, power cables and wirings.

* Again particular credit is recorded for the special interest, and ingenious assistance provided by Mr. E. R. Goldfield and the Picker X-ray Corporation in the designing of this item.

LARGE SCALE REQUIREMENTS SATISFIED

All manufacturers were invited to cooperate with the Army in these developments. Some of them manifested particular interest in one item; some, in another. Contract awards were based upon special facilities and competitive biddings.

It was advantageous to the Army that one manufacturer obtain a contract for the construction of all the units of one particular type. This provided more definite assurance that there would be complete and easy interchangeability of replacement parts. At the same time, it appeared practical and desirable that the greatest possible number of qualified manufacturers be engaged in the overall procurement program. This policy was not only equitable to the manufacturer, but it insured expeditious, continuous and efficient supply.

Regardless of the large quantities of apparatus required, practically all of the production schedules were completed on time. The manufacturers cooperated in a most meticulous and enthusiastic manner; the utmost of engineering skill was exercised, and many ingenious innovations were incorporated into the various items finally produced. Consultations were exchanged back and forth between representatives of industry and the Army. Unfortunately, there was not sufficient time to permit the testing of pilot models under actual or simulated field conditions. By informal arrangements, many unpredictable "bugs" were detected and eliminated just as soon as they became evident during the early stages of actual construction. In addition, a considerable amount of valuable constructive criticism permitted correction of defects as they became apparent as the first few units were placed into operation.

During the phase of preliminary plannings, an effort was made to ascertain the approximate quantities of each item which would be required. This information was of extreme value to the manufacturer, inasmuch as it would permit him to plan and arrange his facilities to the advantage of all

concerned. Various estimates as to the quantities required were suggested, but there was so much variation in these estimates that it was only possible to offer, at that time, statistics that were based primarily on probabilities. The following listing is therefore recorded so as to more definitely estimate the need in the event of a future mobilization:

Item No.	*Name of Item*	*Manufacturer*	*Quantity Supplied*
9605500	X-ray field unit, dryer and loading bin combination: Complete with air circulator; for field processing unit	Buck X-Ograph Co.	1,966
9606000	X-ray field generator: Gasoline powered, to produce approximately 2,500 watts. Complete in chest	D. W. Onan & Sons	6,530
9607000	X-ray field unit portable grid: Replacement grid for 9614500; also suitable for use in bedside or similar type of roentgenography.	Liebel-Flarsheim Co.	1,441
9608508 (110 volt) and 9608510 (110–220 volt)	X-ray field unit, machine, x-ray, 60 cycle: Consists of 1 each of 9608600, 9608700, and 9608808	Picker X-ray Corp.	
	Transformers		8,985
	Controls		9,035
	X-ray tubes		12,056
	Cables		20,380
9609005	Chest MD X-1, old type: Tubestand and chassis for converting 9608508 or 9608510 to a mobile unit; rear wheels 8 inch diameter, front wheels 4 inch diameter	Picker X-ray Corp.	3,706
9609010	Chest MD X-1, new type: Tubestand and chassis for converting 9608608 or 9608510 to a mobile unit; rear wheels 15 inch diameter, front wheels 10 inch diameter.	Picker X-ray Corp.	868
9611500	X-ray field unit processing unit, for darkroom: for film processing	Westinghouse Electric Corp.	2,311
9611700	X-ray field unit processing unit, auxiliary wash tank	Westinghouse Electric Corp.	1,000
9614500	X-ray field unit table unit: for field fluoroscopy, foreign body localization and roentgenography. Complete in chest	Westinghouse Electric Corp.; H. G. Fischer & Co.	2,811 875
9619100	X-ray field unit, bi-plane marker and re-orientating device	Westinghouse Electric Corp.	1,898
9621500	X-ray field unit, fluoroscopic, foreign body localization, complete: With table unit. Shockproof 15 ma. machine for use with both 110 volt and 220 volt current; 1 pair of gloves, 1 apron and 1 pair of goggles included with each assembly	Picker X-ray Corp.	1,588
	Wafer grids having an approximate dimension of 14×17 inch overall and with a 30 inch focal distance, as designed to fit the heavier field table as supplied by Westinghouse and Fischer	Liebel-Flarsheim Co.	3,066
	Wafer grids approximately 12×16 inch focal distance, to fit the Picker Airflow Unit (9621500)	Liebel-Flarsheim Co.	1,724

SHORTCOMINGS WITH RESPECT TO POLICIES

Contrary to the original plannings (and contrary to the practice during World War I) roentgenoscopy did not supplant roentgenography even in the most forward echelons. Films, film storage, and film processing equipment, chemicals, and darkroom facilities were demanded and sup-

plied even in the motorized Evacuation Hospitals and the forward elements of the Field Hospitals. Graphic evidence and permanent records, such as the roentgen-ray film, were believed necessary. The doctors of this war had become roentgenologically conscious. The surgeons wanted to see the roentgenograms. Many of the roentgenologists consoled themselves with the expression that "roentgenoscopy produced a bottle-neck in the handling of the patient, anyway." Even for foreign body localization, anteroposterior and lateral film studies, regardless of distorted anatomical relationships, were preferred by many to the more accurate and more rapid roentgenoscopic foreign body localizations.

Roentgenologists requested a rigid table top; they asked for equipment to permit easier handling of the patient for *roentgenography*—even though it did require moving the patient from the litter to the table top and then back from the table top to the litter. They asked for a moving "Potter-Bucky" diaphragm—for many thought that the factor of *movement* of the grid (versus grid ratio) was the all important factor concerned with clean-up of scattered radiation and fogging.

Some requested a field type of stereoscopic cassette changer. Others requested a field stereoscope. Some wanted a field unit having a capacity of 100 milliamperes (as compared with the 30 ma. provided with the standard type of x-ray field unit). Many of these requests were based upon the inability of the commercial designs of equipment to withstand the rigors of field conditions and also the considerable weight which characterized many of these items. In addition, there were numerous requests for various types of roentgenographic auxiliaries: tunnel changers, spot film and serialographic devices, angulation boards, etc.

MORE RECENT DEVELOPMENTS

In order to provide for some of these wants, the Army School of Roentgenology continued with research efforts, throughout the Emergency; developing items for the immediate requirements of the conflict and formulating plans for a long-range program.

Constructions and reconstructions were made of a field packing chest having a design such as to provide for converting it into various items of office furniture suitable for a temporary field roentgen-ray department. Packing chests had been provided for all items which were originally intended to be used with mobile installations. Other equipment was simply crated. This was the case for the combination film loading bin and dryer, and also the film processing units—the master chemical section and the auxiliary wash section. These items were shipped from the manufacturer in ordinary packing crates.

It seemed impractical to provide a packing chest for each component of these items. Instead, in order to simplify the problem of supply, the handling, and the shipment, the ideal arrangement appeared to be that of a single chest. The inside dimensions of this chest were such as to permit accommodation of any of the above mentioned components—the film loading bin, the dryer, the master chemical tank (of which there were two styles: the compact stainless steel type and a larger bulky wooden type); the pedestal section for the master chemical tank; the auxiliary wash tank (of which there were two styles: a compact stainless steel type and a larger bulky wooden type); and the pedestal section for it. Internal bracings, fixation straps and supporting panels served to secure these items irrespective of the variations of dimensions of the items. In most instances, there remained some space for additional packing of films, chemicals, linens, and other miscellaneous items (Fig. 1*a*, 1*b*, 1*c*, 1*d*, 1*e*).

After this chest was unpacked, it could be converted into one or another of the following items: desk, table, settee, bookshelf, clothes rack, storage cabinet, reserve water tank (90 gallons), or auxiliary wash tank. For the latter two adaptations, there was provision for making connections to community plumbing (Fig. 2*a*, 2*b*, 2*c*, 2*d*, 2*e*, 2*f*).

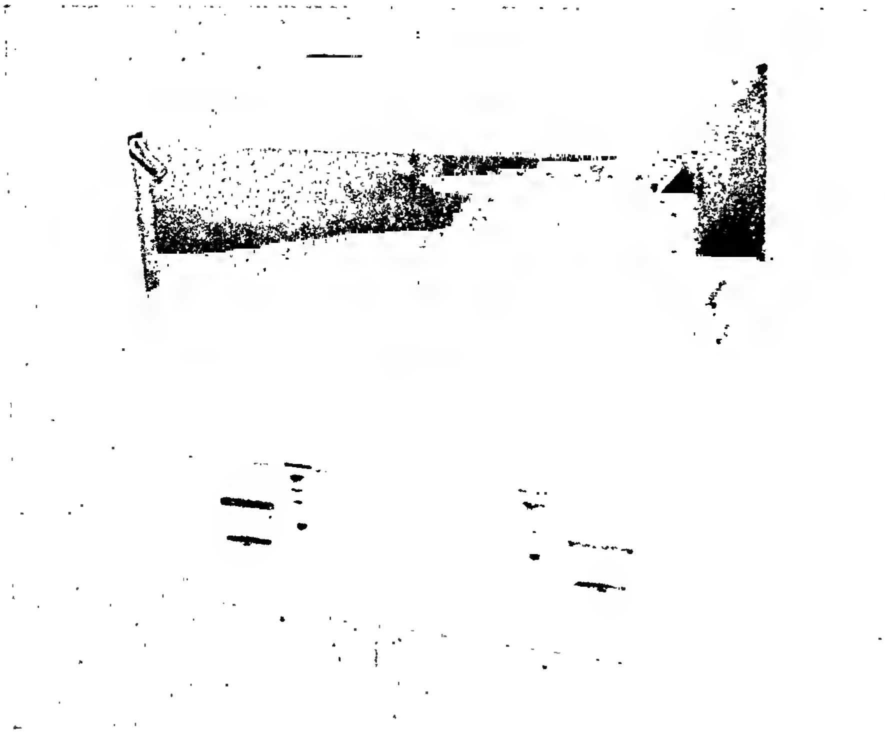


Fig. 1*a*

Fig. 1*a*. Packing chest for accommodating Field Processing Equipment.

Fig. 1*b*. Dryer accommodated in the bottom section of packing chest—top section removed. Note strap fixation.

Fig. 1*c*. Processing tank packed in lower section of chest—top section removed.

Fig. 1*d*. Loading bin packed in lower section of chest—top section removed.

Fig. 1*e*. Pedestal portion of processing tank packed in lower section of chest—top section removed.

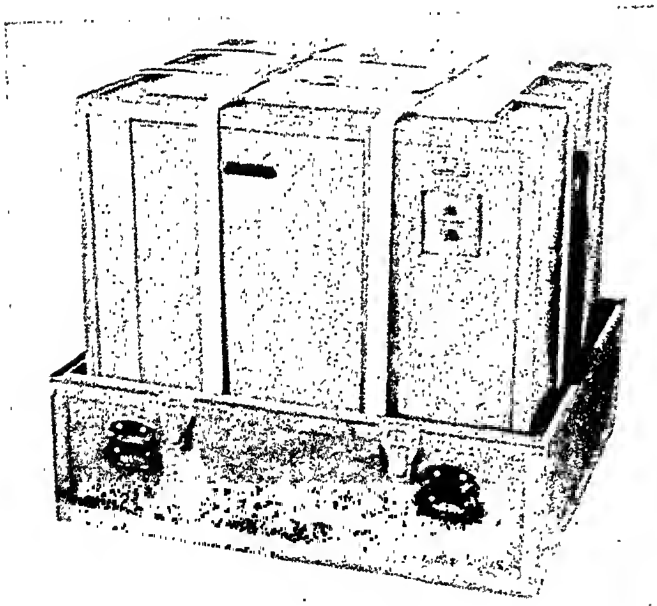


Fig. 1*b*

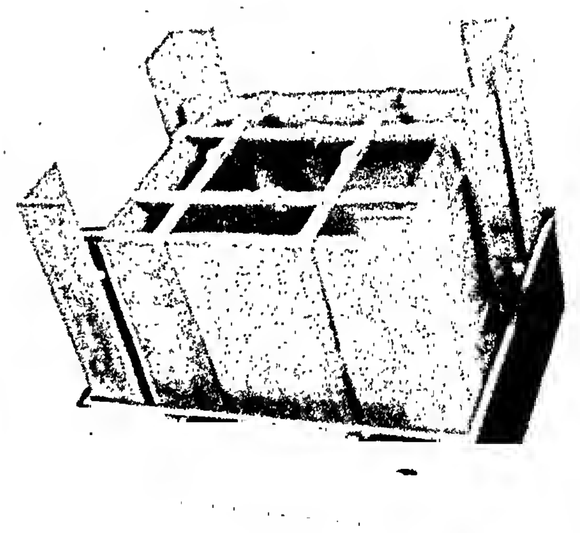


Fig. 1*c*

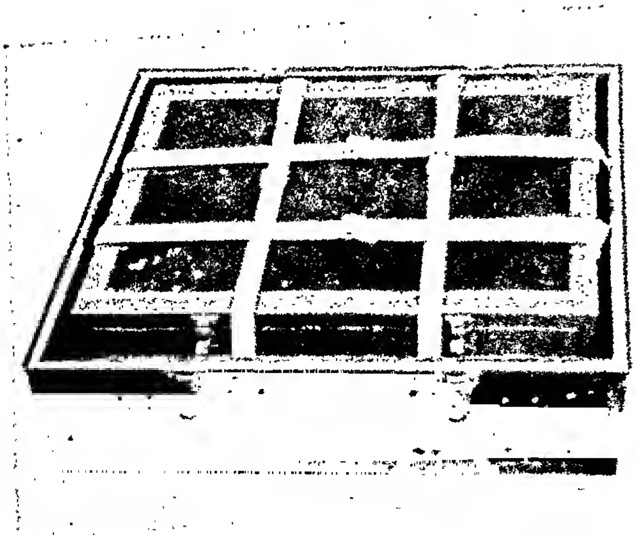


Fig. 1*d*

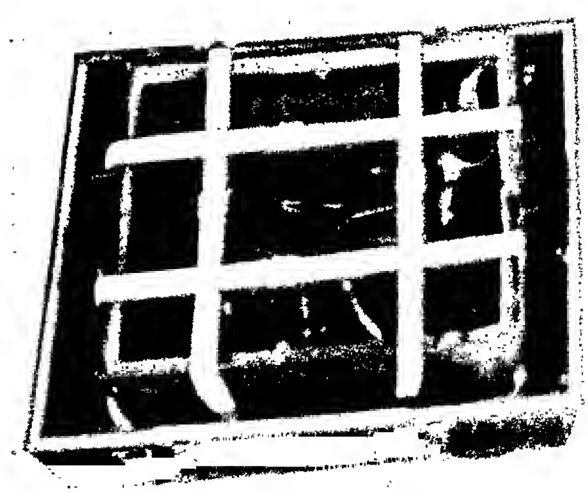


Fig. 1*e*

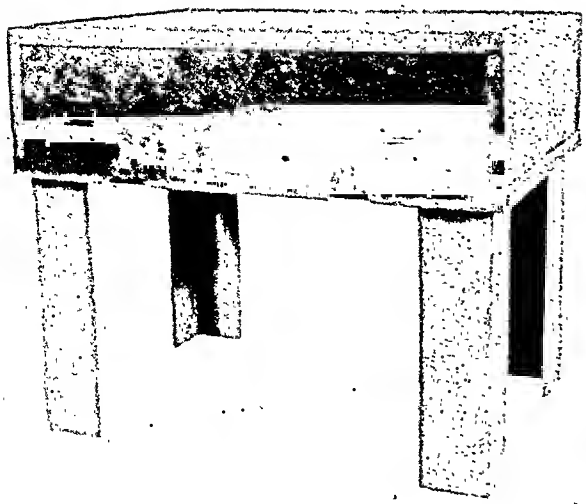


Fig. 2a

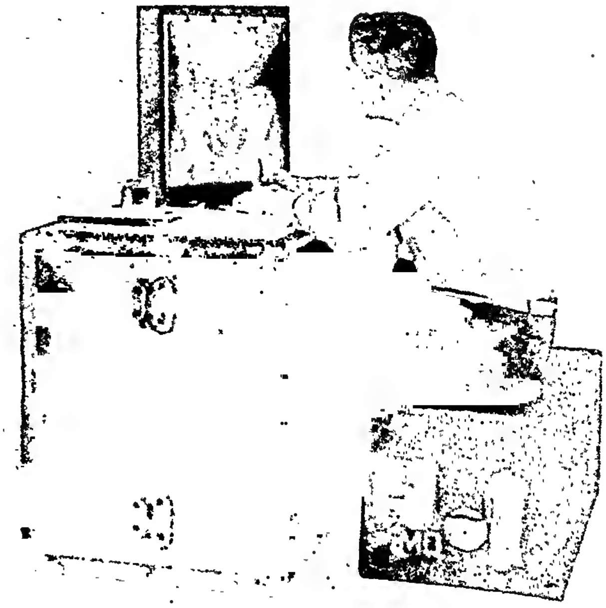


Fig. 2b

Fig. 2c

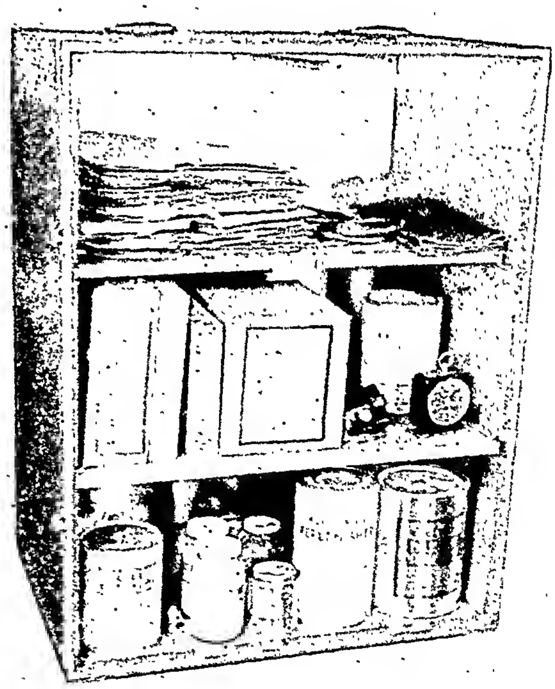


Fig. 2d

Fig. 2a. Bottom section of chest used as a table.
Fig. 2b. Top section of chest used as a desk.
Fig. 2c. Bottom section utilized as bookshelf.
Fig. 2d. Top section utilized as a storage cabinet.

With the assistance of H. G. Fischer and Company, Chicago, Illinois, there was developed a stereoscopic cassette changer, of the field type. The design was such as to permit it to be set up in a few moments' time. It was possible to use it either with the field roentgen-ray equipment or with any other standard design of equipment. There was provision for release of the cassettes by remote electrical control (Fig. 3).

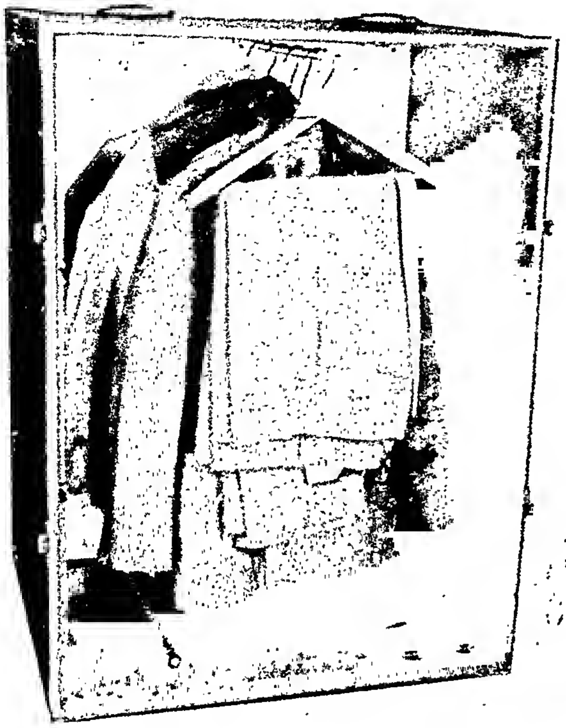


Fig. 2*e*. Top section utilized as a clothes cabinet.

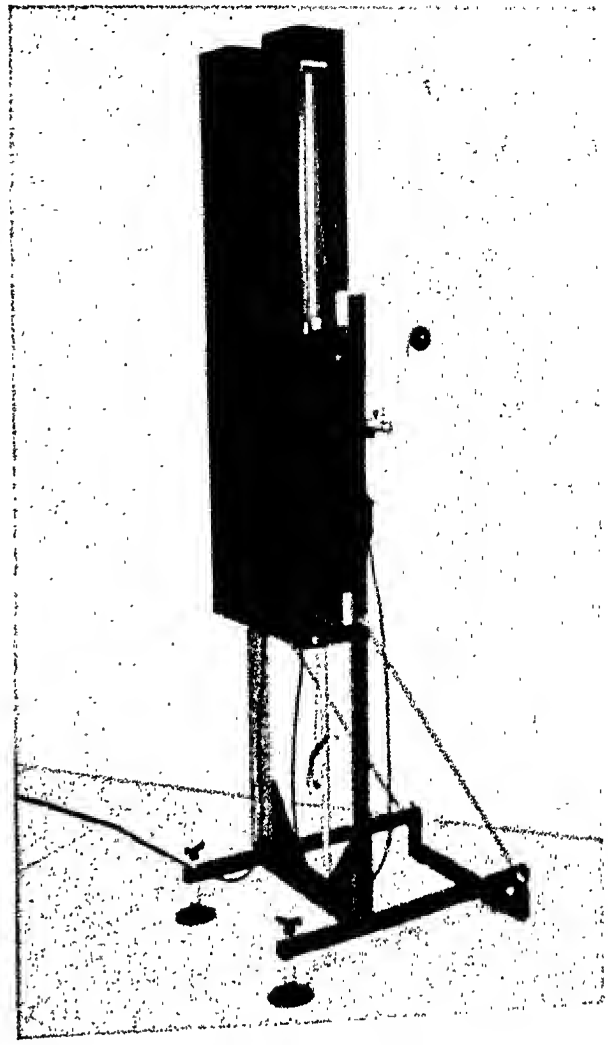


Fig. 3. Stereoscopic cassette changer.

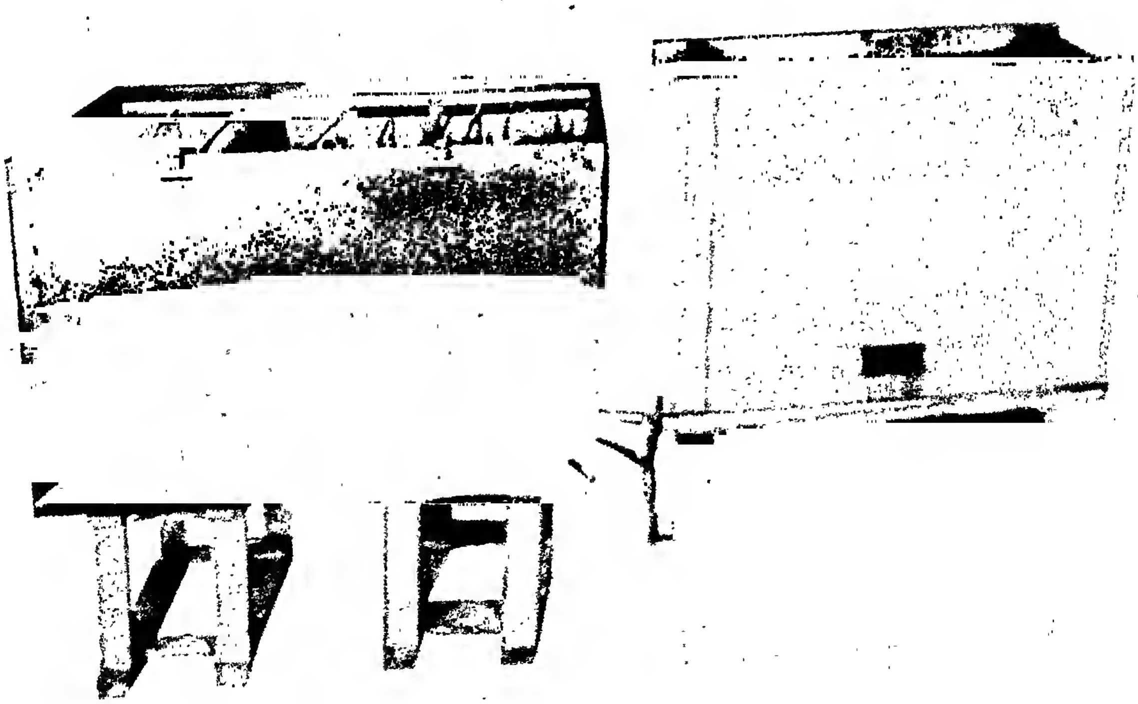
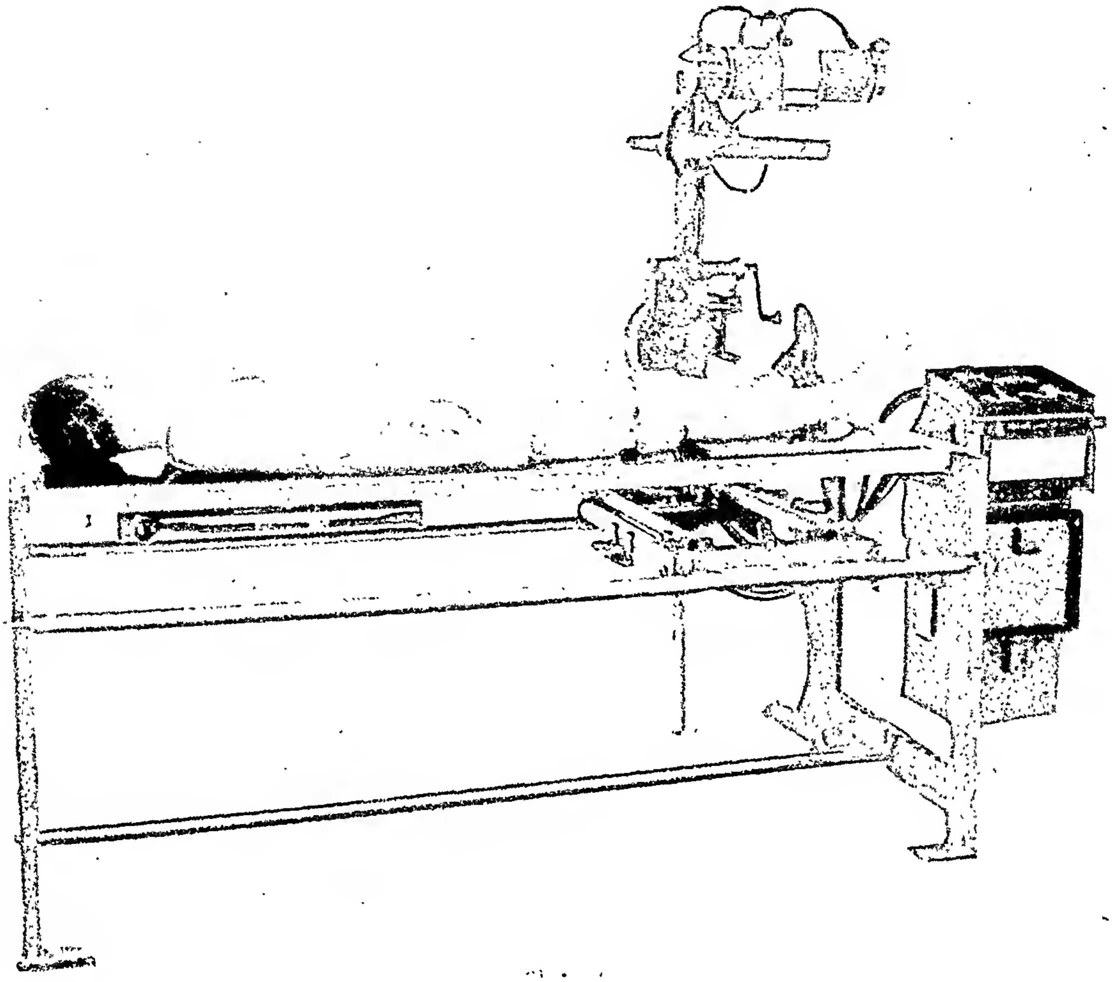


Fig. 2*f*. Top section used as a wash tank. Note arrangement of interior [illegible] processing unit.



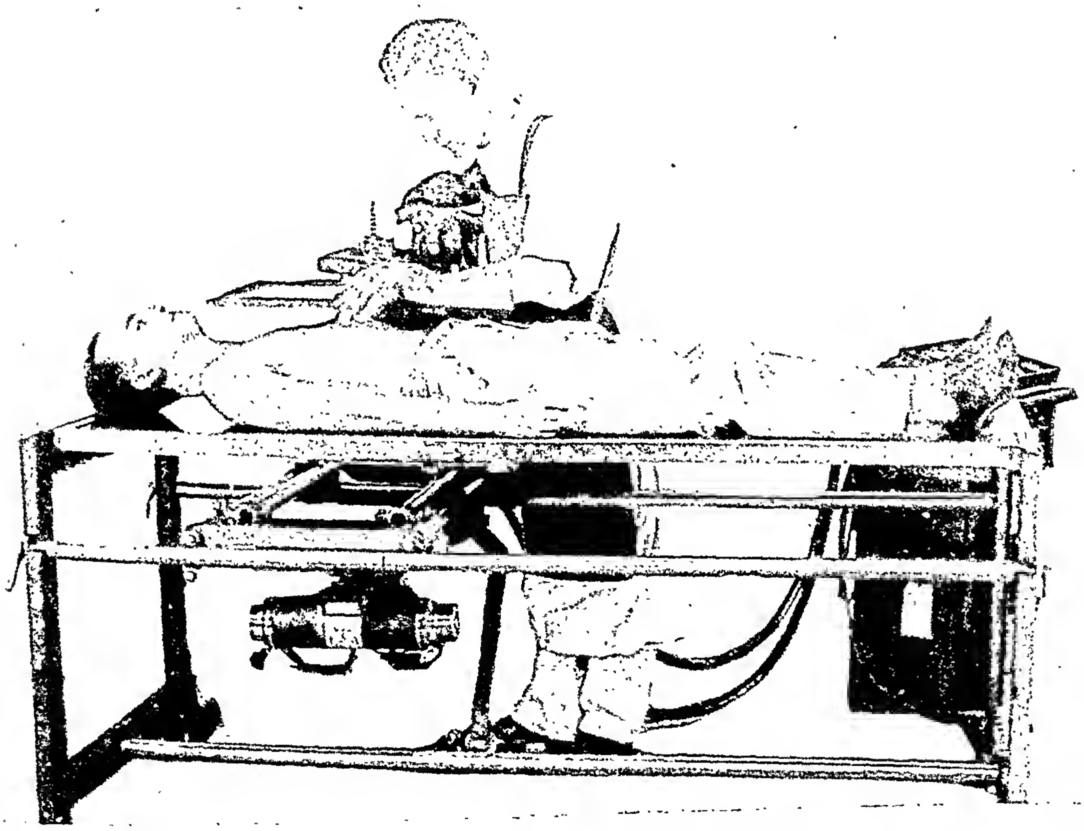


Fig. 4a. (*upper*) Solid table top used in conjunction with field equipment for horizontal roentgenography.
Fig. 4b. (*lower*) Table top positioned for horizontal roentgenoscopy and foreign body localization.

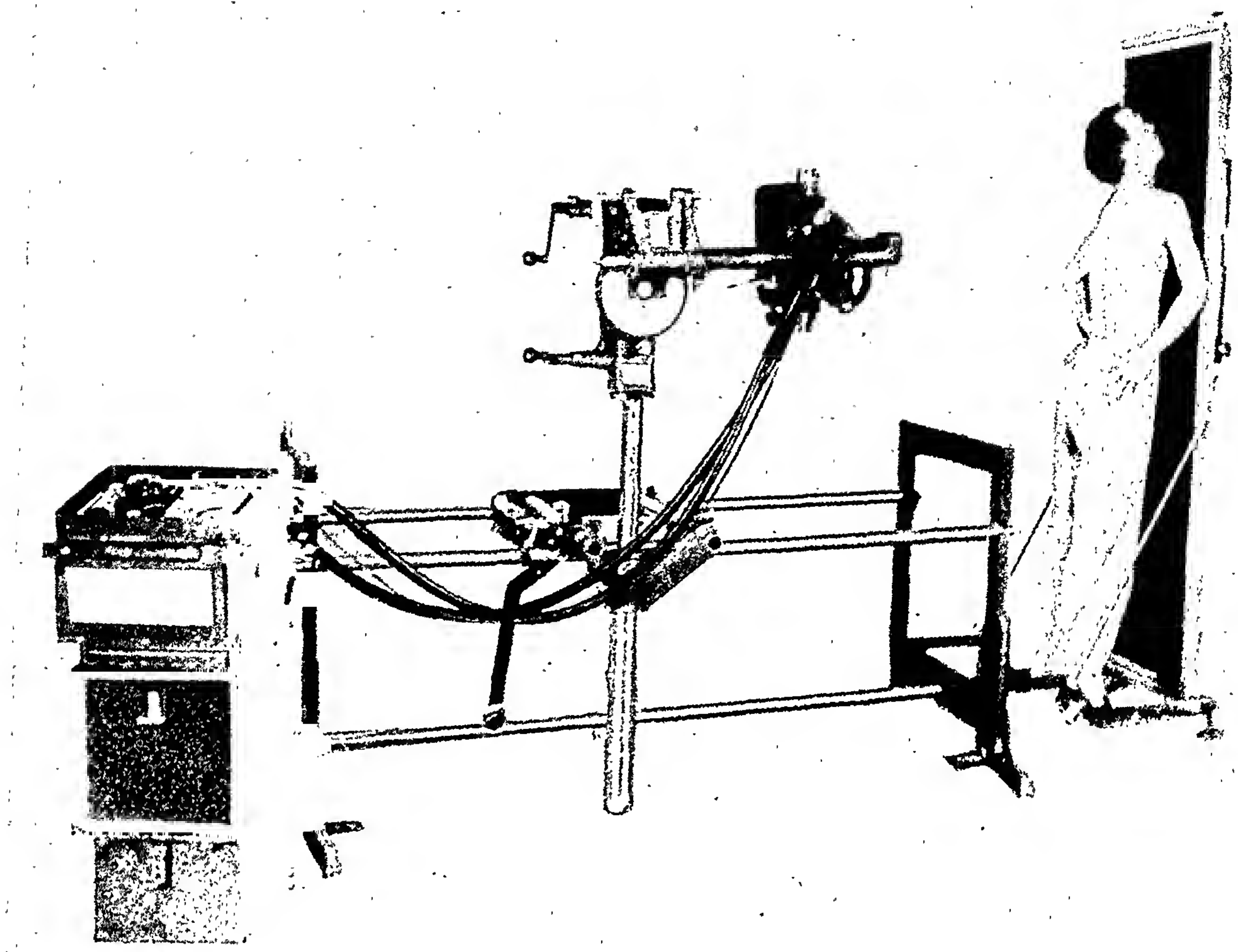


Fig. 4*c*. Table top positioned—at either end of the table—with Potter-Bucky diaphragm for vertical roentgenographic studies.

Fig. 4*d*. Table top positioned for vertical roentgenoscopy.

Solid table tops were constructed by the Picker X-ray Corporation and also by H. G. Fischer and Company. In both instances, Potter-Bucky diaphragms were incorporated. The removability of this table top permitted various adaptations for roentgenoscopy and roentgenography and it also permitted direct placement of the patient and litter, as originally planned (Fig. 4*a*, 4*b*, 4*c*, 4*d*, 4*e*).

A combination spot film and serialographic device with auxiliary components was constructed. This item consisted of a main tunnel housing and auxiliary attachments designed to permit a single, compact unit to be convertible into any of a number of accessory aids. It was designed essen-

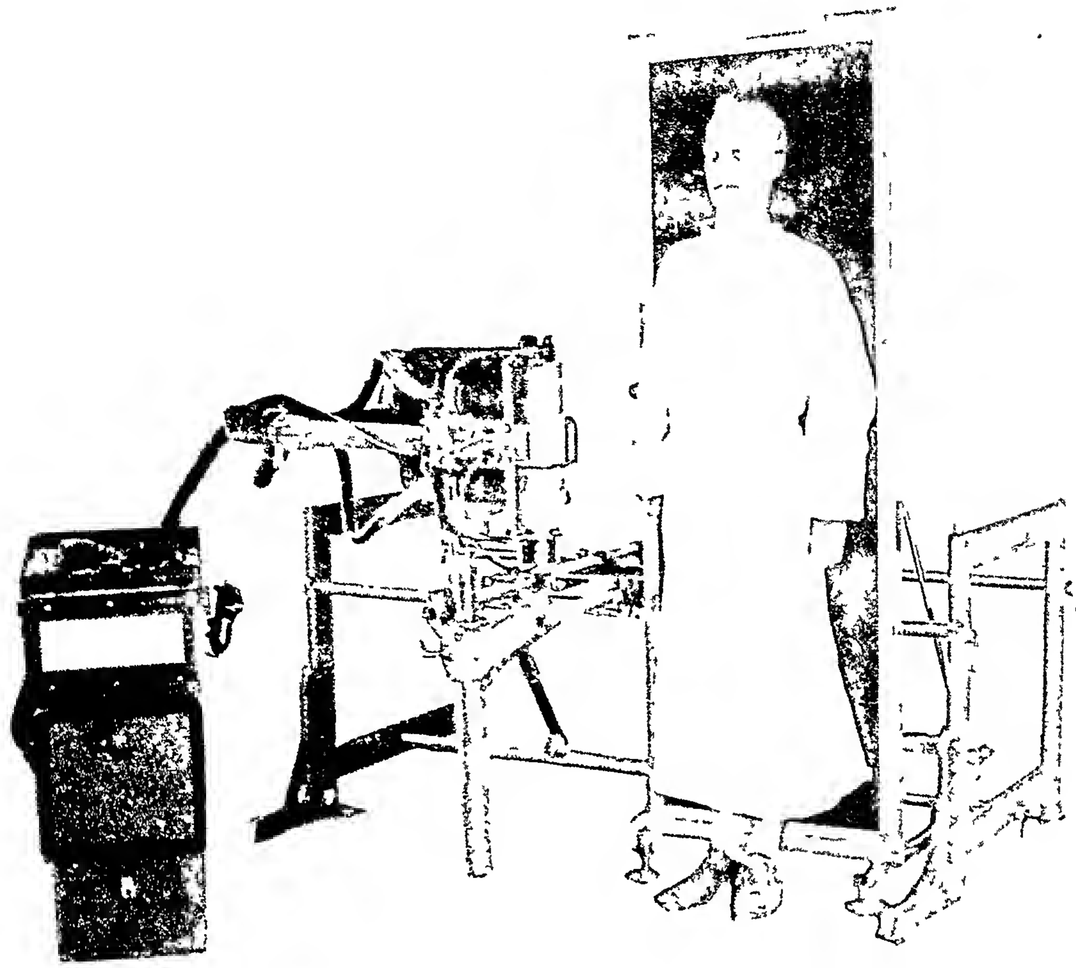


FIG. 4*e*. Table top positioned for vertical roentgenography—at any of the four sides of the table.

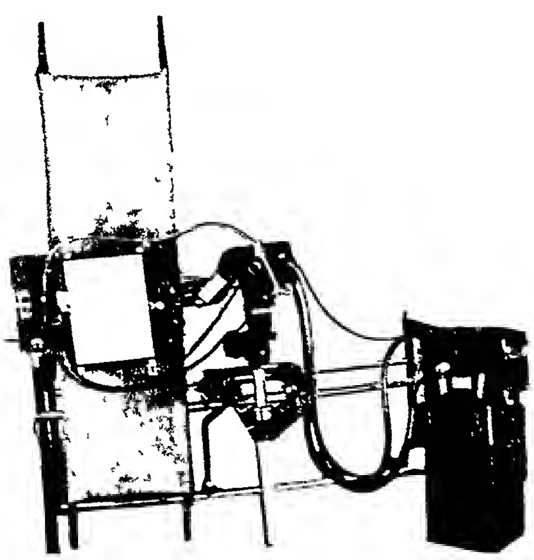


FIG. 5*a*. (*above*) Combination spot film and serialographic device attached horizontally to fluoroscopic screen for use in vertical roentgenoscopy.
FIG. 5*b*. (*right*) Device attached vertically to the screen for use in vertical roentgenoscopy.

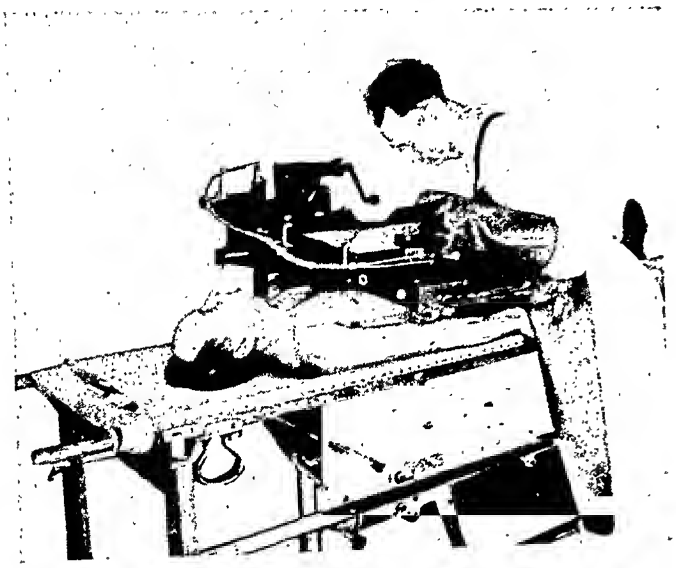


FIG. 5c. Device attached to fluoroscopic screen for use in horizontal roentgenoscopy.

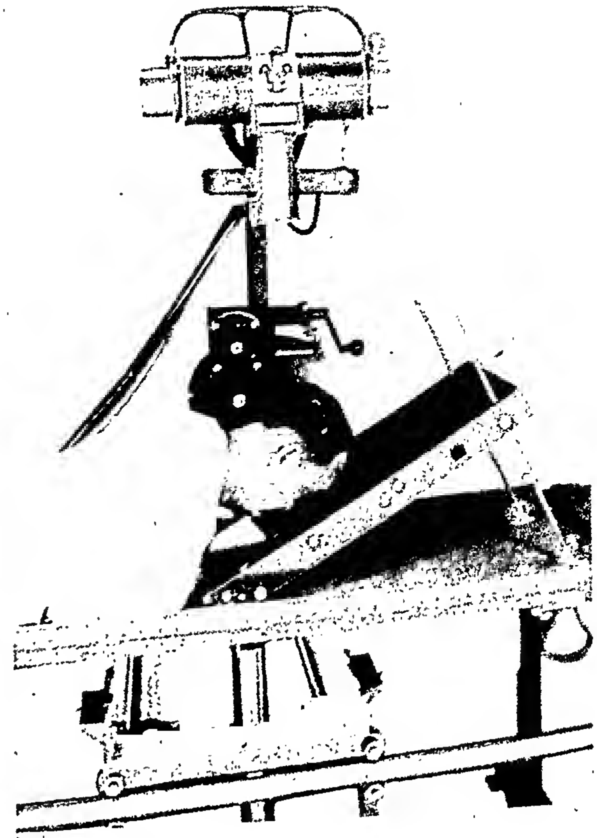


FIG. 5e. Device used as an angle board.

FIG. 5d. Device used as a tunnel changer or stereoscopic cassette changer at the bedside.

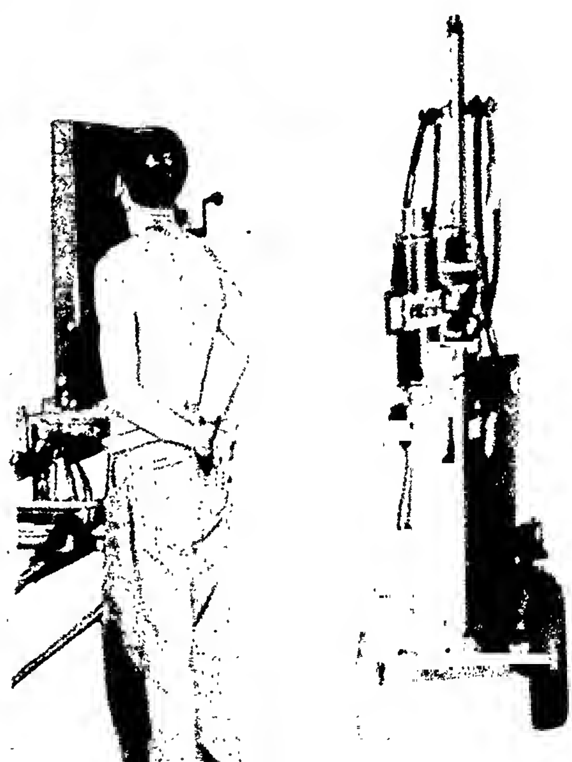


FIG. 5g. Device used as a kymograph. (A special grid could be inserted for this purpose with a change-over plunger provided for connection of the cassette carrier onto a cable moving mechanism.)

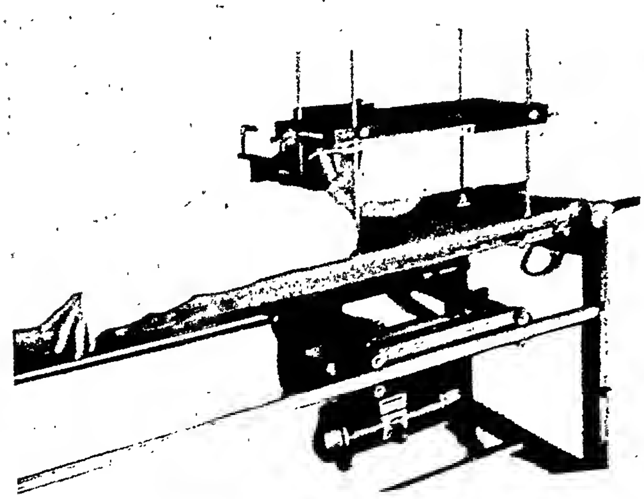


FIG. 5f. Device used for tube under-the-table roentgenography. An arrangement practical especially for maxillofacial fractures.

tially for operation in conjunction with the field roentgen-ray equipment. However, it could also be utilized with other types and designs of standard apparatus. In addition to its adaptation for spot film and serialography (incorporating an automatic change-over circuit for boosting the roentgen tube current from a roentgenoscopic setting to a roentgenographic setting), it could also be used as a stereoscopic cassette changer, tunnel changer, angulation board, for tube under-the-table roentgenography, and as a kymograph. This device was of course intended for large hospital installations (Fig. 5*a*, 5*b*, 5*c*, 5*d*, 5*e*, 5*f*, 5*g*).

Finally, the Picker X-ray Corporation developed a four-valve, full-wave rectification component which could be adapted to the standard field roentgen-ray machine. By this means, it was possible to increase the capacity of the unit from 30 ma. (half-wave) to 100 ma. (full-wave). It was also possible, with this arrangement, to recon-

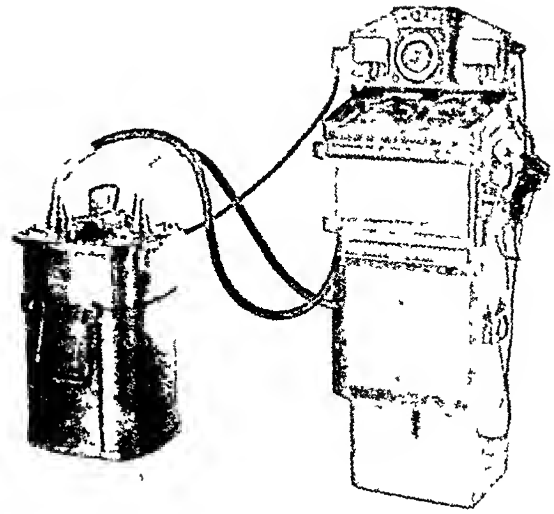


Fig. 6*a*. Close-up of rectification tank and conversion meter unit connected to the field unit to provide four-valve full-wave rectification.

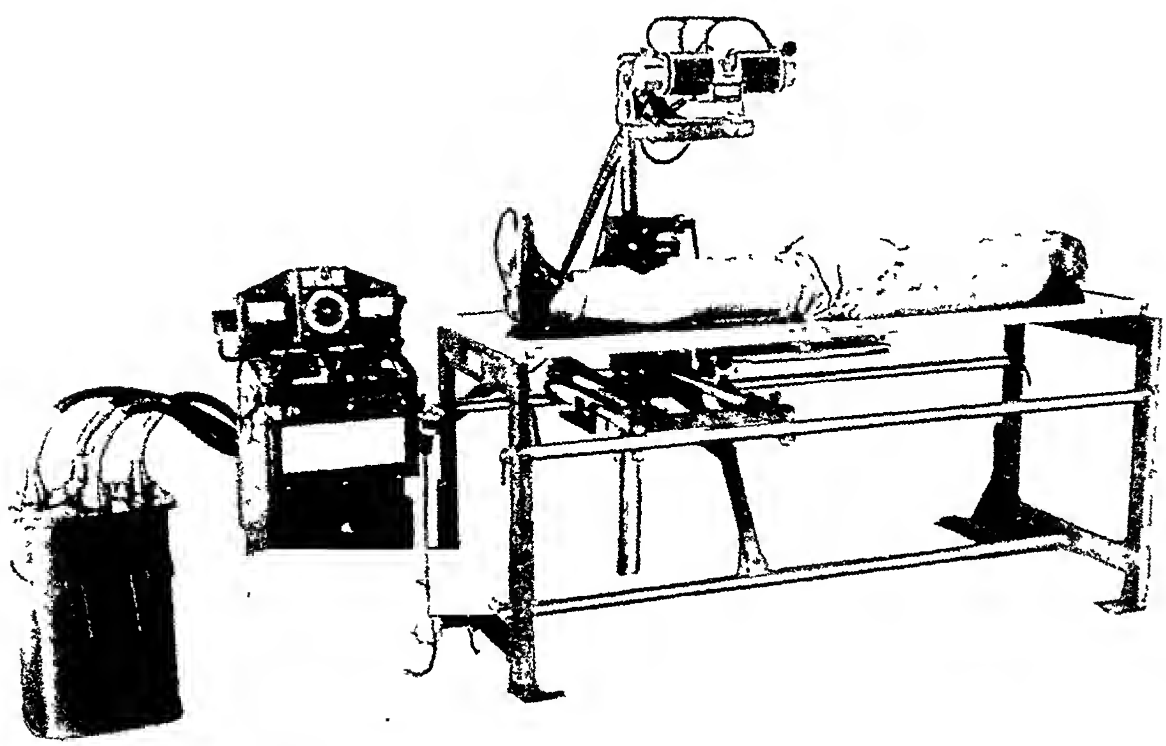


Fig. 6*b*. View of four-valve rectification component operated in conjunction with the field roentgen-ray unit, table unit and rigid table top.

vert the unit to 30 ma. if desired. The model was extremely compact, simple to operate, and rugged. It was contemplated that with the use of this component it should not be necessary to include as standard items any of the commercial high milliamperage table units—equipment which, because of its bulk and weight had been found to be very impractical for transportation and installation at scattered Army hospitals.

SUMMARY

When charged with the planning and development of roentgen-ray equipment suitable for wartime conditions throughout the world, as experienced during the past mobilization and conflict, meager information was available as to the desirable military characteristics of each item of equipment and the quantities of such equipment which would be required to fulfill the demands. With consideration of possible future responsibilities for military planning, there were recorded certain axiomatic principles which have dominated past developments. The quantity requirements of the basic items, such as concerned with World War II, are cited and there are mentioned here certain shortcomings and suggestions.

Specially constructed equipment should not be necessary when the outbreak of war appears to be imminent. The evolution of the design should be gradual and should permit the trial of a few items at a time and thereafter improvements should be made in such items based upon field and fixed hospitals, testings and recommendations. Modern innovations providing mechanical and electrical improvements should be tested and, when practical, they should be incorporated into the strictly Army equipment. In this manner, gradual improvement can be made of any basic item and then there will be assurance that there will always be available a design of proved performance possessing the very finest of engineering developments.

It should not be necessary to have one design of equipment for one type of hospital and a different design for another type of hospital. There should be a standardized line of equipment possessing the required military characteristics permitting it to function under all kinds of terrain and climatic conditions throughout the world. To fulfill this plan, there should be a basic component around which all other components will function. The basic component should be the nucleus. It should be easily portable. It should be rugged. Used alone or with auxiliary components, it should serve the gamut of roentgenologic requirements. It should be possible with this basic component to expand milliamperage capacities and adaptations merely by adding multiples to it or by the addition of simple accessories or attachments. Conventional commercial equipment should not be procured for use where it will be required to function under field conditions. Such equipment should be restricted for those installations where the facilities are similar to those of civilian institutions. There would be an ever constant and progressive development of a strictly military line of equipment. This line of equipment should be inclusive not only of basic items, but also of auxiliary apparatus.

Each item in the military line of equipment should be made up of components easy to assemble or disassemble. There should be no loose or detachable small parts which could be easily lost or misplaced under changing field conditions. No items should be designed to fit into a packing chest. Rather, the equipment should be designed first to accomplish its purpose, and then the packing chest developed to accommodate it. The packing chest should have dimensions which would permit it to be easily packed and transported with other chests. The dimensions and sizes of these chests should be kept to an extreme minimum compatible with requirements. The packing chests should provide for the greatest possible range of adaptation for use when the equipment is unpacked. It should be possible to convert the packing chests into field furniture and hospital office equipment. The chests should be

waterproof, dustproof, and permit fungiproofing, moistureproofing and corrosion treatment of the subject items included within.

Electrically, the equipment should be designed to operate from either community supply or portable generator sets. They should be able to utilize voltages in the 110–250 volt range and possibly 440 volts at 50–60 cycle, alternating current, single-phase. When extreme portability is required, a combination electrical generator and roentgen-ray unit designed for 400 cycle operation might be practical.

In connection with the basic components, there should be developed a complete assortment of auxiliary aids with provision for adaptation without the use of special tools. Here again, single purpose items should be avoided. Every effort should be exercised to provide multiplicity of purpose to the extent of including, two, three, or a half dozen functional adaptations. Some caution must be exercised in this regard, however.

The mode of roentgenologic practice cannot be anticipated. At the present time, the greatest emphasis is directed toward roentgenography; roentgenography versus roentgenoscopy. As group practice, socialization, regimentation and legal medical practices continue to expand, it seems quite likely that there will be continued desire for permanent, graphic film records; roentgenography and repeated *roentgenography* of most patients.

REFERENCES

1. de Lorimier, A. A. Foreign body localization as provided with the United States Army table unit. Am. J. Roentgenol. & Rad. Therapy, 1942, *47*, 307–313.

2. de Lorimier, A. A. Wartime military roentgenology. *Radiology*, 1941, *36*, 391–403.

THE HISTORY OF DOSIMETRY IN ROENTGEN THERAPY

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ROENTGEN rays have become a very important agent in medicine. The possibility of influencing living tissues by their action was recognized within a few months after their discovery and in the early years a considerable amount of more or less casual and empiric therapy was attempted. Some patients were found to be benefited, in others no good was accomplished and sometimes actual harm seemed to result. When a favorable effect had been obtained in one case, there was no assurance that the treatment which produced it could be repeated. Tubes and generators were very irregular in behavior, and little or nothing was as yet known of the significance of the various physical factors. It was evident that some means of measuring dosage was essential before real progress could be made.

The first attempts by physicists to measure radiations had little bearing on the dosage problem. Dorn (1897), using an air thermometer,[illegible] and Rutherford and McClung (1901) with a bolometer,[illegible] attempted to determine the total energy emitted by a roentgen-ray tube or a radium source. The use of such instruments was not practical for the therapist, and there appears to have been no early effort to adapt them or to employ other physical means.

The first definite scheme for dosage measurement was proposed in 1902, and [illegible] then, radiologists and physicists [illegible] to develop more satisfactory [illegible]. Much research has been directed [illegible] accurate, simple, and practical [illegible] standards, and means of [illegible]. A great deal has been [illegible] but the problem is still not [illegible]

[illegible] reactions to [illegible] production of erythema and epilation. The value of the latter in the treatment of ringworm of the scalp was at once evident, provided it could be assured that the epilation would be temporary. It was the need of establishing such assurance that led to one of the first attempts at quantitative measurement of roentgen-ray dosage, the pastille radiometer.

Pastille Radiometers. In 1902, Holzknecht,[46] utilizing the knowledge that certain chemicals underwent color changes under the action of roentgen rays, offered the first dosage measuring instrument, which he called a chromoradiometer. It consisted of a graduated color scale and a series of capsules filled with a solution whose composition was not made public. However, its behavior was not satisfactory and it was soon withdrawn from sale.

In the next two years, other color changes were tested, but nothing practicable was devised until Sabouraud, in 1904, thought of using the color change which had been demonstrated when the platinocyanide of barium was exposed to roentgen rays. In collaboration with Noiré, he devised a very simple radiometer for the one purpose of indicating when an epilating dose had been administered.[81] The standard was a card carrying two colored disks. One, a brilliant green, was the color of unexposed pastilles of the cyanide, the other an orange color, was the shade assumed by a pastille placed half way between the skin and the tube target, when an epilating dose had been delivered at the skin. In practice the pastille was put in the half-way position, the tube operated for a time thought to be less than sufficient, the test pastille compared with the standard, and this intermittent irradiation carried on until the test piece showed the desired change. For the

determination of this one dose, with a fixed quality of radiation, the instrument was satisfactory. However, it had no sort of graduated scale for determining fractions of the full dose. Furthermore, its readings were affected by changes in the quality of the radiation, hence it was of limited applicability.

Bordier, Holzknecht, Hampson, and others,[8,40,47,49] soon developed radiometers with graduated color scales, so that known fractions of the epilating or erythema dose could be administered. Of these, the most successful and widely used was the improved model of Holzknecht (1910). The standard color index was a celluloid band 4½ inches long, colorless at one end, and shading gradually through orange to deep brown at the other. Beside this was a band of colorless celluloid. The pastilles were mounted on small strips of cardboard; for each test one was exposed and another used as control. After the exposure the pair were inserted into the frame so that two semicircular pieces were in contact to form a complete circle. The exposed semicircle was under the colorless strip of celluloid, the control under the colored. The pair was moved along under the celluloid screens until the two halves appeared to be of the same color, which was increasingly darker the greater the amount of radiation. A graduated scale indicated dosage up to the full color change, which corresponded to the epilation dose, when the pastille was at half distance. Since at full distance the dose delivered is only one-fourth as great, considerably larger doses could be measured by placing the pastille on the skin instead of half way. Readings had to be made very quickly—within less than a minute after the end of the exposure—since the color faded rapidly.

Pastilles are not used at the present time, but they were of great service before the development of modern methods.

Fluorescent Standards. Since the excitation of fluorescence in certain substances was the earliest and one of the most spectacular effects observed to be produced by the roentgen rays, it was to be expected than an effort would be made to employ this phenomenon in measurement. Coutremoulins[13] (1902) proposed to compare the fluorescence produced by a beam of rays to the intensity of a standard lamp at a definite distance. Guilleminot[39] (1907) compared the luminosity due to the roentgen-ray beam to that due to a standard radioactive source. Some years later Wintz and Rump[102] (1926) described a precision instrument, the roentgen photometer, in which the fluorescent light was measured by means of a Lummer-Brodhun photometer. None of these, however, attained any widespread use.

Photographic Radiometers. Stern,[91] in New York, appears to have been the first to use a photographic method of dosage measurement; his paper was published in 1903. Subsequently others elaborated on it; the best known was probably the Kienböck Quantimeter (1904).[50,51] This consisted of a standard scale of photographic half tones, white at one end, almost black at the other, with seven intermediate grays calibrated in units based on the epilating dose. Strips of silver bromide paper enclosed in light-proof envelopes were furnished. One of these was placed on the skin in the center of the field of radiation, and removed and developed at the end of the treatment. If fractional treatments were being given, one strip could be carried through the entire series, and developed at the end, to record the total dose, while others could be used to check the daily doses. The strips, after careful development, were compared with the standard. The photographic method had the advantage of affording a permanent record of the treatment; however, it had several serious disadvantages. Like the pastilles, it has now been replaced by more accurate instruments.

Selenium Cell. The discovery that the electrical resistance of metallic selenium was changed under the action of visible light or of roentgen rays, led to attempts to employ it in the measurement of radiation

quantity. The Fürstenau intensimeter developed in 1915,[31] was the only successful commercial instrument of this type, and it was never very widely used, partly because of inherent instabilities and partly because within a few years better methods became available. It was, however, the first practical instrument by means of which it was possible to measure the output of the roentgen tube while it was in operation. The active selenium was enclosed in a light-tight cell at the end of a long cable consisting of two electric leads attached to the two ends of the metal strip. This comprised one arm of a Wheatstone bridge (an instrument for measuring electric resistance), the rest of which was enclosed in a box to which the leads were connected and which could be kept at some distance from the roentgen tube. The indicating galvanometer was also in the box, reading on a glass scale set into one side of it. The selenium cell was placed on the skin of the patient, in the center of the irradiation field and the bridge adjusted so that the galvanometer reading was zero. When the roentgen rays were turned on, the resistance of the selenium decreased, the bridge was unbalanced to a degree indicated by the galvanometer reading. Within limits, this was proportional to the intensity of the radiation. A scale was provided for reading this intensity in "I units" and conversion data were supplied for relating these to the Sabouraud and Holzknecht units.

Physical Factors of Radiation. As long as roentgen tubes and sources of high potential were subject to great individual variations, the output of radiation fluctuated from exposure to exposure, and even from minute to minute, and it was necessary to measure dosage for each treatment. After the introduction of the closed core transformer and the invention of the Coolidge tube, equipment was available which operated with remarkable steadiness. It then became possible to control dosage by controlling the physical factors. These were voltage, milliamperage, target-skin distance, filter, and time of exposure. (The size of the irradiated field, which is usually listed as a physical factor, need not be considered here.) If a radiologist decided to use a certain voltage-filter-distance-milliampere combination, he could determine experimentally the time required to produce an epilation or an erythema. Then by giving longer or shorter exposures he could administer fractions or multiples of the erythema dose. However, he could not alter any of the other factors without re-determining the standard dose.

In 1915 and 1916, Shearer[83,84] collected theoretical and experimentally determined data regarding variation in dose with variation in physical factors and established a formula which was long the sole basis for dosage determination for many therapists, particularly dermatologists. This was based on "observed" facts* that (*a*) the intensity varies directly as the milliamperage; (*b*) the intensity varies directly as the square of the voltage; (*c*) the intensity varies inversely as the square of the distance from the target to the skin. Hence the dose of radiation for any treatment varies as

$$\frac{\text{milliamperes} \times \text{kilovolts} \times \text{kilovolts} \times \text{minutes},}{\text{distance} \times \text{distance}}$$

and the result of a change in any one of these can be calculated. It must be noted that the filter does not appear in this formula; it holds for any given filter, but the basic dose must be re-determined for each one.

MacKee[61] promoted the practical use of this formula, determining basic doses for all filters customarily employed in dermatologic practice.

During this period the radiologist, who customarily worked with fairly fixed sets of factors except for time, fell into the habit of specifying his doses in terms of milliampere-minutes, the product of the milliamperes and the time of exposure. Of course the number of milliampere-minutes required to deliver an erythema dose is

* Actually (*b*) is true only over a very limited range, as has been shown by more extensive observation.

dependent on voltage, filter, and distance, and these should always have been explicitly stated. Unfortunately, in many old records this is not the case.

Ionization Methods. All the foregoing dosage measuring schemes have now been displaced by methods depending on ionization; that is, a change in electrical conductivity when matter is traversed by roentgen rays. This phenomenon was observed by Röntgen within a few weeks after his discovery of the rays. Electroscopes and electrometers, were utilized by the Curies in France, Wilson and others in England, and Geitel and others in Germany, in the first few years of study of roentgen and radium radiations. However, the possible use of these instruments in dosage measurement was not considered for some time. The first reference found in the literature is an article published in 1905 by Milton Franklin,[28] lecturer in electroradiotherapy at New York Polyclinic Hospital. After pointing out defects in photographic and pastille methods, and explaining that simple reading of meters meant little with the unstable equipment then in use, he described his electroscope. This was a metal box containing an aluminum fiber mounted on a metal post, and an electrostatic charging device. The beam of rays entered the box through a narrow aperture, and windows permitted the entrance of light and the observation of the discharge of the fiber. A scale was provided for reading varying degrees of discharge, which corresponded to varying doses of radiation.

One or two other instruments were reported in which the entire electroscope was placed in the beam of radiation, although it was recognized that this was not satisfactory. Villard,[99] in 1908, designed a combined ionization chamber and electrometer, with a scale calibrated in Holzknecht units. However, he suggested a new unit: "The unit of quantity of x-rays is that amount which liberates by ionization one electrostatic unit of charge per cubic centimeter of air at normal temperature and pressure." This is essentially the same as the roentgen which was officially adopted a number of years later; at that time, however, neither the method nor the unit received much consideration.

A few years later (1914), Szilard[92,93] approached the dosage measuring problem more critically than had anyone up to that time. He reviewed the various methods used in dosimetry, and pointed out that ionization had been most generally employed by physicists in their investigation of roentgen and radium radiations. The question had been raised of the parallelism between ionization and biological effects; he admitted it had not been answered, but added that this was also true for all the other methods. The advantages of the ionization method were listed:

1. The x-rays themselves are measured, hence the measurement is independent of all radiation factors.
2. Ionization is unaffected by any physical factors other than the radiation.
3. The radiation can be measured in absolute electrical units.

He then set forth the requirements for a satisfactory and practical instrument—requirements which still cover most of the factors to be considered:

1. The instrument must integrate the total quantity of radiation, whether this is given at a single exposure or with interruptions (i.e. no time factor).
2. The indications must be consecutive, the scale showing not only units but fractions of units.
3. The readings should be given by the motion of a needle on a scale, so as to avoid any personal error.
4. It must be possible to make the measurements in the actual place that the radiation is required, wherever that may be, whilst the scale should be easily read at some distance from the irradiated area, so as to protect the operator from injury.
5. The instrument must only be sensitive to the radiation at one definite point—the receiver—it must therefore be adequately screened from all perturbing or parasitic action of the rays.

6. The apparatus must work equally well with any installation.

A proper ionization instrument was stated to fulfill all these conditions; and he presented his, the iontoquantimeter. The ionization chamber, of 1 cubic centimeter volume, was enclosed in thick lead on all sides except the top, which was of very thin aluminum to admit the radiation. It was attached to one end of a long cable of flexible rubber, carrying an embedded wire connected to the center electrode and shielded with a flexible metal tube. This wire led to the electrometer, with a needle reading directly on the scale.

Szilard proposed a new unit instead of Villard's. He felt that the fundamental significance of the ion should be recognized, and his unit was "the amount of radioactive energy necessary to set free a single ion in air under normal conditions of temperature and pressure." Of course this was much too small for practical use, so the practical unit was to be the mega-mega-ion or 10^{12} ions; this is equivalent to 340 electrostatic units.

Christen[11] (1914) accepted Szilard's unit and instrument. However, he called attention to the fact that the dose is not the quantity of radiation impinging on a surface, but the energy absorbed. He therefore proposed as the unit of dose "10^{12} ions absorbed by one cubic centimeter of dry air at 15° C. and at normal atmospheric pressure," and suggested that it be called a szilard. He then suggested that it might be even better to calculate in ergs the amount of energy whichwould be required to set free 10^{12} ions. The dose would then be expressed in ergs per cubic centimeter.

Thus, by 1914 the units accepted at the present time had been proposed. However, a considerable amount of time was to elapse and much research to be carried out before they were formally accepted.

Both Szilard and Christen encountered practical difficulties with their ionization chambers. The reasons for this were complicated—partly due to neglect of such precautions as the employment of saturation potential on the chamber, and partly due to ignoring the effect of scattered and secondary radiations from the chamber itself or from surrounding objects. Physicists had long been aware of the significance of these factors in ionization measurements, but their importance was not realized in practical dosimetry. Duane[19] called them to attention repeatedly, after 1914, pointing out particularly that ionization chambers used for standardization should be of the "open air" type. That is, the beam of radiation should enter and leave the chamber by diaphragms and the ionization in the air should be due only to the primary beam and not to any secondary or scattered rays from any metal or other solid parts of the apparatus. He reworded Villard's definition to state that "the electrostatic unit is that intensity of radiation which produces under saturation conditions one electrostatic unit of current per cubic centimeter of air under normal pressure and temperature" and designated it as E.

In 1918 Krönig and Friedrich[55] published their comprehensive study on roentgen-ray measurements. They used the unit defined by Villard, calling it *e*. In 1921 Solomon[87] proposed his unit, R (Röntgen) defined as "the intensity of a roentgen radiation producing the same ionization per second as one gram of radium placed 2 cm. from the ionization chamber and filtered with 0.5 mm. of platinum."

By this time it had become apparent that some form of ionization unit would be preferable to any other method of measurement then available. It was also realized that standardizing the output of a roentgen tube was not the only thing necessary in describing the dose of radiation received by the patient, but that the physical factors of the radiation, the size of the patient, the position of the tumor mass, and other conditions had to be considered. Hence research proceeded along two lines, standardization and clinical dosage. With regard first to the matter of standardization, two interlocking problems had to be settled—the best choice and definition of

the unit, and the development of measuring methods to insure that the unit was correctly realized and employed. Studies were carried out in physical-radiological laboratories in various parts of the world, particularly in Germany, France, England, Sweden, and the United States, and the results presented first at national and then at international radiological meetings. Space does not permit a detailed history of this development, but the main points should be mentioned.

The Unit of Quantity of Radiation. In Germany the unit first proposed by Villard[99] was adopted. Behnken[4] reworded the definition as follows: "The absolute unit of roentgen-ray dosage is defined as that amount of radiation which, in one cubic centimeter of air at 18° C. temperature and 760 mm. mercury pressure, on full utilization of the secondary electrons arising in the air, and with avoidance of wall effects, produces such a degree of conductivity that the quantity of electricity measured under saturation conditions amounts to one electrostatic unit. The unit of dose is called one Roentgen and is indicated by R." Both at the Reichsanstalt and at various university laboratories, ionization chambers and measuring instruments were developed to meet the conditions laid down by the definition.[55,56] The German Roentgen Ray Society adopted the unit.

In France, the Solomon unit, R, was promptly accepted. This differed considerably from those of the other countries both in definition and in the method of measurement. Whereas, as will be seen, in all other countries the standard instrument was developed as a large open air ionization chamber, so that the measurements depended only on ionization in air, Solomon's instrument was a small thimble chamber of a particular construction.[88] The results of these differences contributed to the long lasting confusion over dosage specifications and controversy regarding the acceptance of an international unit.

In England studies were carried out at the National Physical Laboratory, mainly under the direction of Kaye and Laby, but little appears to have been published from there prior to 1928.

In Sweden, Sievert and his associates at the Radiumhemmet were the principal workers. Their first interest was in the measurement of radium radiations, but as they began to employ roentgen rays extensively they also entered that field.

In the United States, Duane, as mentioned earlier, had been one of the first to point out the importance of the open air chamber. He continued to study the problem at Harvard University, while the physics departments of the Memorial Hospital and the Cleveland Clinic, and somewhat later the Bureau of Standards, also engaged in extensive research.

International Standards of Quantity. The First International Congress of Radiology met in London in 1925, and the matter of an international dosage unit was one of the principal topics. The German and French delegations had definite, but very different, recommendations; the others felt that the time was not yet ripe for decision, and the question was deferred until the Second International Congress of Radiology at Stockholm in 1928. In the meantime improvements were made on all equipment, and many more data accumulated.[6,20,33,88 and others]

At the Second International Congress, a number of papers were presented on the question, notably one by Failla[24] setting forth in detail what must be accomplished by a standard open air chamber, and how this might be achieved. The International X-ray Unit Committee, consisting of twenty-four members from fifteen countries, submitted provisional recommendations which were adopted by the Congress.[94] The unit was specified as "the quantity of X-radiation which when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produces in one cubic centimeter of atmospheric air at 0° C. and 76 cm. mercury pressure, such a degree on conductivity that one electrostatic unit of charge is measured at

saturation current." The unit was to be called the "roentgen" and designated by r.

This definition was left unchanged at the Third International Congress of Radiology in Paris in 1931. At the Fourth International Congress of Radiology in Switzerland in 1934, the question was raised of broadening the definition so that the unit could also apply to gamma rays. Finally, at the Fifth International Congress of Radiology, in Chicago in 1937, the International Committee for Radiological Units, of twenty-three members, representing twelve countries, adopted a definition which was again to be regarded as provisional until the next congress, and which is the one used at present:[77]

1. The International Unit of *quantity* or *dose* of x-rays or gamma rays shall be called the "roentgen" and shall be designated by the symbol "r".

2. The roentgen shall be the quantity of x- or gamma-radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying 1 e.s.u. of quantity of electricity of either sign.

Standard Ionization Chambers. As soon as an international definition was first established, various laboratories in the different countries developed standard instruments, against which secondary standards could be calibrated. Inter-laboratory and international comparison of these standards was highly desirable. However, the standard chambers were heavy, and difficult to transport, and it was necessary to develop small secondary chambers, which could be calibrated against the national standards and carried abroad for comparison with other instruments. Glasser and Portmann[33] developed such small chambers and by means of them compared several standard chambers in this country, finding agreement to ±4 per cent. Several French instruments calibrated by the Solomon standard and sent to the United States were found to agree among themselves within ±5 per cent, and to give a ratio of 1 roentgen equivalent to 2.1 Solomon R. Seven German instruments, however, only agreed to within ±13.5 per cent, and showed a difference of 50 per cent between the German and the American roentgens, the former being larger. This discrepancy was intolerable and Behnken constructed two chambers with special care, brought one himself to America and sent the other by Jäger by a different route.[5] With these instruments they found only 4 per cent instead of 50 per cent difference from Glasser and Portmann's standard. They also checked the Solomon unit and found a ratio of 2.26 R to 1 r. A considerable number of other comparisons through secondary standards were made in various European countries.

In 1930 Taylor,[94] at the United States Bureau of Standards, devised a guarded field standard ionization chamber that made it possible to construct a standard instrument in portable size. This he took to Europe and was thus able to make direct comparisons in the standards laboratories of England, Germany, and France.[95] Careful comparisons under standardization conditions showed less than 1 per cent discrepancy among the four standards, when the Solomon ratio was taken as 2.29 R = 1 r. As a consequence of this study, Solomon adopted the guarded field chamber instead of the closed thimble chamber. From the physical point of view, the roentgen is now an accurately established unit.

Clinical Dosimetry. While all this research was being carried out on the standard dosage unit and measuring device, dosimetry was also developing along other lines. Fundamentally, the need for dosage determination is in relation to the patient—how much radiation is administered and what can be expected from it. The earliest devices were designed to show when an erythema or epilation dose had been administered, and for many years some form of erythema dose was accepted as the unit. The literature contains numerous articles relating the erythema dose to Holzknecht, Kienböck, or other units, for different voltages and methods of admin-

istering the radiation. After standardization of machines by roentgen output as measured in air chambers became common, radiologists still desired to know how many roentgens corresponded to an erythema dose and the latter continued to be the clinical unit for some time.

In the earliest attempts at dosage measurement, no distinction was made between the dose in air, that on the surface of the patient's body, or that actually received by the tissues supposed to be undergoing treatment. However, it was promptly realized that absorption of radiation in superficial tissues reduced the amount arriving deep within the body, and efforts were made to measure this reduction. Since at this stage the influence of target-skin distance and the contributions of scattered radiation to the tissue dose were not recognized, it seemed that any method of measuring the absorption would give the desired information. Thus, with any of the early dosimeters a sheet of material could be interposed between the tube and the indicator and the depth dose measured.[3,50,52,51] Furthermore, it was assumed, after some preliminary tests, that absorption in 1 mm. of aluminum was equivalent to that in 1 cm. of tissue or water, and depth doses were considered on that basis.

As soon as absorption measurements began to be made, it became evident that a layer of material in the path of the beam, while it decreased the intensity, increased the penetrating power, and so *filtration* began to be used.[58,68,69,78] Actually Röntgen had foreshadowed this in his third paper, in March, 1897, in which he said, "If we imagine a substance divided into layers of equal thickness, placed perpendicular to parallel rays, each of these layers is more transparent for the transmitted rays than the one before it. . . . The rays emitted by a discharge-apparatus consist of a mixture of rays which are absorbed in different degrees and which have different intensities.[82] . . ."

The first mention of effect of *target-skin distance* found in the literature is by Williams[101] in 1903. Dessauer[14] (1912) was strongly impressed with the necessity of having homogeneous irradiation throughout the part of the body undergoing treatment, and pointed out that both distance and filtration could contribute to this condition.

In pursuance of his search for homogeneous irradiation, Dessauer[15] constructed a "phantom" of strips of animal tissue 1 cm. thick. Between these he placed Kienböck strips, which were all developed simultaneously, thus giving a "depth dose" actually measured instead of calculated. He found that this dose was greater than would be expected on a basis of absorption and inverse square law, and correctly attributed the increase to scattered and secondary radiation arising within the phantom. Barkla[1,2,] and others had demonstrated the existence of these radiations earlier, but their significance in therapy had not been appreciated.

Since no way was known of calculating the contribution of the secondary radiation to the depth dose, more satisfactory phantom measurements, simulating actual treatment conditions, were desirable, and in 1918 Krönig and Friedrich[55] published their extensive and painstaking studies. They used a small ionization chamber on the end of a flexible cable well shielded from radiation effects, and as a phantom a tank of water 35 cm. in diameter and 25 cm. deep. When they tested different ionization chambers it became evident that the material of which the chambers were constructed was very important, as would be expected because of secondary radiations from the walls. The character and amount of these secondary rays not only depended on the nature of the wall material, but on the voltage and filter used in producing the roentgen-ray beam. For this reason the chambers of such instruments as Szilard's[92] with walls of heavy metal, were not suitable for dosage measurements. Krönig and Friedrich compared chambers of thick and thin alumi-

saturation current." The unit was to be called the "roentgen" and designated by r.

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2. The roentgen shall be the quantity of x- or gamma-radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying 1 e.s.u. of quantity of electricity of either sign.

Standard Ionization Chambers. As soon as an international definition was first established, various laboratories in the different countries developed standard instruments, against which secondary standards could be calibrated. Inter-laboratory and international comparison of these standards was highly desirable. However, the standard chambers were heavy, and difficult to transport, and it was necessary to develop small secondary chambers, which could be calibrated against the national standards and carried abroad for comparison with other instruments. Glasser and Portmann[33] developed such small chambers and by means of them compared several standard chambers in this country, finding agreement to ±4 per cent. Several French instruments calibrated by the Solomon standard and sent to the United States were found to agree among themselves within ±5 per cent, and to give a ratio of 1 roentgen equivalent to 2.1 Solomon R. Seven German instruments, however, only agreed to within ±13.5 per cent, and showed a difference of 50 per cent between the German and the American roentgens, the former being larger. This discrepancy was intolerable and Behnken constructed two chambers with special care, brought one himself to America and sent the other by Jäger by a different route.[5] With these instruments they found only 4 per cent instead of 50 per cent difference from Glasser and Portmann's standard. They also checked the Solomon unit and found a ratio of 2.26 R to 1 r. A considerable number of other comparisons through secondary standards were made in various European countries.

In 1930 Taylor,[91] at the United States Bureau of Standards, devised a guarded field standard ionization chamber that made it possible to construct a standard instrument in portable size. This he took to Europe and was thus able to make direct comparisons in the standards laboratories of England, Germany, and France.[92] Careful comparisons under standardization conditions showed less than 1 per cent discrepancy among the four standards, when the Solomon ratio was taken as 2.29 R = 1 r. As a consequence of this study, Solomon adopted the guarded field chamber instead of the closed thimble chamber. From the physical point of view, the roentgen is now an accurately established unit.

Clinical Dosimetry. While all this research was being carried out on the standard dosage unit and measuring device, dosimetry was also developing along other lines. Fundamentally, the need for dosage determination is in relation to the patient—how much radiation is administered and what can be expected from it. The earliest devices were designed to show when an erythema or epilation dose had been administered, and for many years some form of erythema dose was accepted as the unit. The literature contains numerous articles relating the erythema dose to Holzknecht, Kienböck, or other units, for different voltages and methods of admin-

num, carbon, and horn, calibrating each against their open air standard chamber. They found that the horn chamber gave readings in the same ratio to those of the standard over a much wider range than any of the others, and therefore used it for their final depth dose measurements. They also compared these chambers with other types of dosimeter—Kienböck, Fürstenau, Sabouraud-Noiré.

Krönig and Friedrich then made careful and detailed measurements of the radiation on the surface and at various depths in the phantom, for a range of fields and filters. By covering the region of the primary beam, they actually measured the secondary radiation. And they studied the distribution of the radiation throughout the field, demonstrating a slight decrease toward the edge of the geometrical beam and an abrupt drop outside it. This work may be considered the basis of modern determination of tissue dosage. Many investigators since then have carried out much more extensive studies, realizing that actual measurement was necessary for all practical sets of physical factors.[9,16,26,59, and others] Dessauer and Vierheller[16] developed charts showing the distribution of radiation in vertical and horizontal planes in beams of various sizes. The term *isodose charts*, coined by Friedrich and Glasser with regard to distribution of radiation around radium sources[30] is now generally applied to such distribution charts in the vertical plane. The use of such charts in actual size in conjunction with life-sized anatomical cross-section diagrams for accurate determination of dose at any specified point within the body, was advocated by Failla,[23] Weatherwax and his associates,[100] and others.

Glasser and his associates were particularly concerned with constructing a small thimble ionization chamber whose walls should have the same secondary radiation as air, or be "air-wall."[29] Such a chamber should give readings parallel to the standard open air chamber over a very wide range of quality. Very satisfactory instruments of this type have now been developed.[36] Sievert, Glasser, and others developed small air-wall chambers in the form of condensers which could be separated completely from the measuring electrometer during exposure to the radiation.[31,62,86]

One other development deserves mention, although it has not yet led to any practical result. Since the effective dose of radiation is the energy *absorbed* by the tissues, it would be highly desirable actually to determine this, as pointed out by Failla and others.[22] This has not yet proved practical. It is accepted that ionization produced in tissue is proportional to energy absorption, and that ionization per gram of air is for practical purposes equivalent to that per gram of tissue, *under identical circumstances of irradiation.* Hence ionization in air has generally been adopted as a satisfactory method of determining dosage. However, mention should be made of attempts to fill the ionization chamber with organic liquid and thus more closely simulate conditions in the tissue.[89,96] Up to the present time, such chambers have not proved of practical value. More recently, as will be discussed later, Mayneord has proposed a method of calculating energy absorption from isodose curves and thereby expressing total body dose.

At this stage in the development of dosimetry it was possible by means of standard open air chambers to measure accurately in roentgens the output of radiation in air, and by means of air-wall thimbles, the ratio of radiation delivered anywhere within the body to that falling on the surface. But the relation of the surface dose to the air dose was still not accurately established. The air wall thimble could measure roentgens correctly in air, after it had been calibrated against a standard, for a wide range of radiation qualities, but it was not certain whether this range was sufficient to account for the very soft portion of the secondary radiation at the surface of the body, so that doses delivered in the tissues could be expressed

in roentgens. There were also other possible errors to be considered. The development of the extrapolation ionization chamber by Failla made possible the absolute measurement of tissue dose, both at the surface and within the depths of the phantom.[25,75] It was then found that, over a wide range of quality of primary beam, suitably constructed thimble chambers could be employed to measure surface and depth doses. As the voltage range employed in therapy has extended into both higher and lower regions, special standard and air-wall chambers have been devised to meet the new conditions.[57,70,72,73]

Thus, the problem was settled of reconciling measurement in air in terms of roentgens and in tissue in terms of fractions of an erythema dose, or other biological unit. At the present time, dosage is specified in terms of roentgens delivered at the point where the radiation is utilized.

In practice, the output of the roentgen-ray tube is measured by means of an air-wall thimble chamber which has itself been calibrated against an open air standard chamber. With modern equipment the output is usually very constant, so that it need be measured only at intervals. Knowing the roentgens per minute in air, or the total roentgens delivered in air, the radiologist refers to published charts or tables to determine the roentgens per minute or total roentgens on the surface of the body or at any desired depth.[35,64, and others] Or he may decide what dose he wishes to administer to the tumor itself, and by means of the same tables determine the necessary exposure times.

A number of dosimeters are on the market in Europe and America which satisfactorily measure the tube output in air. Most of the European instruments have the air-wall thimble chamber permanently attached to the current measuring device through a shielded cable. The one in general use in the United States is of the condenser type. Instruments are also available for measuring the actual dose on the skin of the patient during treatment. These have not met with general acceptance. They are expensive, complicated, and, in view of the satisfactory dosage tables available, not particularly desirable.

At this point mention should perhaps be made of the *monitor* ionization chambers mounted in the roentgen-ray treatment cone and reading continuously while the machine is in operation. These are not dosimeters in any sense of the word, but simply, as their name implies, indicators that the apparatus is functioning correctly. When the roentgen-ray output is calibrated with a proper air-wall chamber, the reading of the monitor is noted, and as long as it continues to give identical readings and *voltage and filter remain unchanged*, the output is as measured. Since these monitors usually contain sheets of aluminum through which the beam passes, the ionization is largely due to secondary radiation. Any small change in quality of primary beam results in an unknown change in secondary radiation. Therefore, it is not practicable to calibrate such an instrument and use it as a measure of dosage.

The Specification of Quality. Up to the present point, little has been said about the measurement of *quality* of radiation. Röntgen observed that the greater the length of the parallel spark gap, the more penetrating the x-ray beam.[32] He studied the quality by observing the penetration through a "platinum-aluminum window," a piece of platinum foil and a ladder of aluminum. Either roentgenoscopically or photographically he determined the thickness of aluminum having the same transparency as the platinum, and found that it increased as the rays were filtered.

The Benoist penetrometer (1902) was based on the same principle.[7] It consisted of a silver disk surrounded by a circular aluminum ladder. The aluminum steps were numbered, and the one which matched the silver disk represented the quality in B units. At that time it was believed that silver was "achromatic" with respect to roentgen rays; that is, that all qualities

penetrated it equally, whereas aluminum and many other substances were "chromatic," so that the differential was a true measure. Although this was disproved, the method was still more widely used than any other for a long period.

Villard[98] in 1908 devised an ionization chamber to give an instantaneous reading of quality. This was really a double chamber with the common wall forming a filter. The reading of the electrometer gave the ratio of the unfiltered to the filtered beam; it was calibrated according to the Benoist scale.

In 1912, Christen introduced the concept of *half-value layer* as a measure of quality.[10] He felt that tissue or water should be used, but since this was impractical he substituted bakelite. His apparatus contained a sheet of heavy metal, covered with regularly spaced small holes of such dimensions that the sum of the areas of the holes was just half the area of the sheet. Beside this was a ladder of bakelite. A fluorescent screen was mounted at such a distance from the metal and bakelite that roentgen rays passing through the holes did not show the individual perforations, but produced a uniform illumination. Since half the area of the plate was open, the beam passing through it was just half of the original quantity. The thickness of bakelite which transmitted radiation illuminating the fluorescent screen to the same degree as the perforated plate was the half-value layer. Christen also called attention to the fact that in inhomogeneous radiation the second half-value layer was considerably greater than the first, whereas in truly homogeneous radiation they were equal. Hence the ratio of second half-value layer to first furnished a measure of the homogeneity of the beam.

Szilard[92] considered the methods of Villard and of Christen the "only irreproachable ones," but proposed that the *absorption coefficient* in air would have more meaning. Since, however, he determined this by finding the half-value layer in water and multiplying by a constant, he really offered nothing new.

Various other devices, such as the sklerometer of Klingelfuss,[53] which depended on special electric circuits in the secondary of the roentgen-ray generator, never attained widespread use.

In the United States the specification of quality by voltage or *equivalent spark gap* was most commonly employed, during early years of therapy.[85] The spark gap gives a measure of peak voltage, which determines the minimum wavelength in the beam of roentgen rays. This, however, is a very small part of the entire beam, and the length of the spark gap gives no information about the radiation comprising the remainder. It is therefore not a satisfactory method of quality determination. Furthermore, with the development of "constant potential" installations with large condensers in the secondary circuit, and with other modern improvements, direct application of spark gaps is often impracticable.

The *spectrometry* of roentgen rays led to a better understanding of the meaning of quality, but the complete spectrum was obviously not practical for a radiological specification. It was shown, however, that there was a mathematical relation between peak voltage exciting the roentgen-ray tube, and minimum wavelength in the spectrum. Seemann[82] (1924) developed a simple and rugged spectrometer for determination of minimum wavelength, which enjoyed a certain popularity. Since specification of minimum wavelength is subject to the same criticism as that of spark gap, the method is not satisfactory.

Instead of the minimum wavelength, some sort of average value which should more nearly describe the entire spectrum, seemed desirable, and Duane proposed the *effective wavelength*.[18] This is the wavelength of the monochromatic roentgen ray that has the same absorption in 1 mm. of copper as the whole beam under consideration. Other suggestions were an *average wave-*

length, obtained from an average absorption coefficient, or the *average absorption coefficient* itself, in a specified material. A metal, usually copper, was advocated instead of the air or water used by Szilard. Christen's idea of half-value layer was also favored, but again a metal was preferred to water. Holthusen and Gollwitzer[45] used copper, while Meyer and Braestrup[66] selected aluminum. Mayneord and Roberts,[65] after a critical discussion of methods of quality specifications, concluded that the simple half-value layer was not satisfactory, but recommended that if it was to be used, tin was the best medium. No one of these methods gives a rigid specification of quality; beams "equivalent" by one method are not necessarily so by another.[71] Any one of them could, however, be used within certain limits if general agreement on these limits could be obtained.

A different approach to the subject was that of Taylor and Singer[97] (1934) who made absorption curves in aluminum and in copper for roentgen rays produced at definite constant potentials. A similar absorption curve taken for any beam could be compared with the standard series and its constant potential equivalent determined.

International Standards of Quality. At the Second International Congress of Radiology, the matter of quality specification was considered, and left in a rather indefinite state. Voltage, filter, and general character of high tension apparatus were to be stated, and either half-value layer in "a suitable material" or effective wavelength. At the Third International Congress of Radiology, it was stipulated that in addition to tube voltage, the half-value layer should be specified; in copper if it exceeded 0.1 mm., and in aluminum for less penetrating rays. The Units Committee for the Fourth International Congress recommended that for exact physical measurements, complete absorption curves in copper or aluminum were required but that for practical purposes the quality might be expressed by the first and second half-value layers of the same materials. The International Committee for Radiological Units of the Fifth International Congress of Radiology specified that:

> For most medical purposes it is sufficient to express the quality of the x-radiation by the half value layer in a suitable material: Up to 20 kv. (peak) cellophane or cellone; 20–120 kv. (peak) aluminum; 120–140 kv. (peak) copper; 400 kv. up (peak) tin. For a more definite specification of the quality of the radiation the complete absorption curve in the same material is preferable.

It is recognized that the quality of the radiation changes as the beam passes into the body, becoming steadily less penetrating. Some attempts have been made to measure the quality where the radiation is actually absorbed, with the idea that this might have more significance in therapy than the quality emitted by the tube. Quimby and McNattin[76] made actual absorption curves within the depths of a paraffin phantom, by surrounding their ionization chamber with concentric shells of copper. In this way the half-value layer could be determined at the site of utilization of the rays; for filtered 200 kv. roentgen rays of half-value layer 1.14 mm. copper in air, the half-value layer at 10 cm. depth was 0.7 mm. Clarkson and Mayneord[12] carried out experiments using a double ionization chamber, one section made entirely of carbon, the other incorporating a copper absorber in the walls. However, the problem is technically difficult, and while of theoretical interest, has not been demonstrated to be practically important.

Any discussion of dosimetry in radiology would be incomplete without some mention of its relation to biological reactions. The early literature contains many references to the relation between the various proposed units and the erythema dose or skin unit dose. Numerous workers have made extensive studies with biological test

objects in comparison to ionization chambers in efforts to arrive at true biological dosimetry. Thus, to mention but a few, Jüngling,[48] and Glocker and his associates[37] used bean roots, Holthusen,[44] *Ascaris* eggs, Wood[103] and Packard,[67] *Drosophila* eggs, Henshaw,[41,43] various seeds and eggs.

Work with living organisms inevitably led to the realization that a knowledge of the effect of the *rate of administration* of the radiation was an essential part of biological dosimetry. This had been pointed out by Christen[11] in 1914. Its importance when treatment is given by protracted or fractionated techniques is very great, and at the present time little definite information is available. The studies on recovery as related to erythema production by Reisner[79] and by Quimby and MacComb,[60,74] of Henshaw,[42] on time of cleavage of marine invertebrate eggs, and of others,[38] have only furnished an introduction to the matter. The time factor is at present one of the outstanding problems in dosage determination.

The other is the question of "body dose" or total amount of energy absorbed by the patient. The number of roentgens delivered to a deep-seated tumor with any given set of physical factors may be twice as great for a large field as a small one, but the actual amount of energy absorbed by the patient's body may be many times as great for the large field. The importance of total body dose was early pointed out by Christen.[11] Stenstrom[90] again called attention to it in 1924. In recent years, intensive study has been done, particularly by the British group of radiation physicists.[21,62,63] Mayneord has proposed as the unit the gram-roentgen, the energy conversion when one roentgen is delivered to one gram of air, which is approximately 85 ergs. Since this is very small, his practical unit is one million times as great, the megagram-roentgen, which is equivalent to about 2 gram calories.

SUMMARY

The purpose of this paper has been to present a historical survey of dosimetry in roentgen therapy from its beginnings to the present time. It is fitting, at this fiftieth anniversary of Röntgen's discovery, to review critically what has been accomplished and to look ahead at what needs to be done. The measurement of quantity of roentgen radiation in air is definitely settled. In clinical dosimetry, theory is ahead of practice, and there are still unsolved problems. However, the available information, properly used, puts radiation therapy on a reasonably exact basis, as far as its physical aspects are concerned. The question of quality measurement is not settled, but present standards permit satisfactory exchange of information.

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REFERENCES

1. Barkla, C. G. Secondary roentgen radiation. *Phil. Mag.*, 1906, *11*, 812.
2. Barkla, C. G., and Sadler, C. A. Homogeneous secondary roentgen radiations. *Phil. Mag.*, 1908, *16*, 550.
3. Baxmann, A. Die Tiefenwirkung der mit verschiedenen Instrumentarien erzeugten Röntgenstrahlen. *Strahlentherapie*, 1914, *4*, 312-321.
4. Behnken, H. Die Eichung von Dosismessern in der Physikalisch-Technischen Reichsanstalt. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1923-1924, *31*, 479-481.
5. Behnken, H. Zur Frage der Röntgendosiseinheit. *Strahlentherapie*, 1928, *29*, 192-198.
6. Behnken, H., and Jäger, R. Die deutsche Einheit der Röntgenstrahlendosis. *Ztschr. f. tech. Physik.*, 1926, *7*, 564.
7. Benoist, L. Le radiochromomètre et la définition expérimentale des diverses sortes de rayons X et radiations similaires. *Arch. d'électric. méd.*, 1902, *10*, 129-134.
8. Bordier, H., and Galimard, J. Action des rayons X sur les platino-cyanures et en particulier sur celui de baryum. *Arch. d'électric. méd.*, 1905, *13*, 323-326.
9. Borell, H. Experimentelle Untersuchungen zur Tiefendosierung harter Röntgenstrahlen mit besonderer Berücksichtigung der Streustrahlung. *Strahlentherapie*, 1923, *14*, 239-361.
10. Christen, T. Ueber einige aktuelle Fragen der Röntgenphysik. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1914, *21*, 1-22.

11. Christen. T. Radiometry. *Arch. Roentg. Ray,* 1914–1915, *19,* 210–219.
12. Clarkson, J. R., and Mayneord, W. V. The "quality" of high-voltage radiations II. "Quality" within a scattering medium. *Brit. J. Radiol.*, 1939, *12,* 168–180.
13. Coutremoulins, G. Recherche d'une unité de mesure pour la force de pénétration des rayons X et pour leur quantité. *Compt. rend. Acad. d. sc.*, 1902, *134,* 649.
14. Dessauer, F. Die physikalischen und technischen Grundlagen der Tiefenbestrahlung. *Strahlentherapie,* 1912, *1,* 310–324.
15. Dessauer. F. Die physikalischen und technischen Grundlagen bei der Radiumbestrahlung und der Röntgenbestrahlung und die wichtigsten Fehler. *Strahlentherapie,* 1914, *4,* 452–463.
16. Dessauer, F., and Vierheller, F. Die Tiefenwirkung der Röntgenstrahlen. *Strahlentherapie,* 1921, *12,* 655–690.
17. Dorn, E. Ueber die erwärmende Wirkung der Röntgenstrahlen. *Wied. Ann.*, 1897, *63,* 160.
18. Duane, W. Roentgen rays of short wavelengths and their measurement. Am. J. Roentgenol., 1922, *9,* 167–171.
19. Duane, W. Measurement of dosage by means of ionization chambers. Am. J. Roentgenol. & Rad. Therapy, 1923, *10,* 399–405.
20. Duane, W., and Lorenz, E. Standard ionization chamber for roentgen-ray dosage measurement. Am. J. Roentgenol. & Rad. Therapy, 1928, *19,* 461–469.
21. Ellis, F. Volume dosage in deep x-ray therapy. *Brit. J. Radiol.*, 1942, *15,* 174; 194.
22. Failla, G. Dosage in radium therapy. Am. J. Roentgenol., 1921, *8,* 674–685.
23. Failla, G. Objective method for administration of x-rays. *Acta radiol.*, 1925, *4,* 85–128.
24. Failla, G. Criteria for design of a standard ionization chamber. Am. J. Roentgenol. & Rad. Therapy, 1929, *21,* 47–63.
25. Failla, G. Measurement of tissue dose in terms of the same unit for all ionizing radiations. *Radiology,* 1937, *29,* 202–215.
26. Failla, G., and Quimby, Edith H. Economics of dosimetry in radiotherapy. Am. J. Roentgenol. & Rad. Therapy, 1923, *10,* 944–967.
27. Farmer, F. T. Condenser ionization chambers for measurement of x rays in body cavities; physical problems in their design. *Brit. J. Radiol.*, May, 1945, *18,* 148–152.
28. Franklin, M. Method of measuring the x-rays. *New York Med. J.*, 1905, *81,* 802–807.
29. Fricke, H., and Glasser, O. Theoretical and experimental study of small ionization chamber. Am. J. Roentgenol. & Rad. Therapy, 1925, *13,* 453–461.
30. Friedrich, W., and Glasser, O. Ueber die Dosenverhältnisse bei inkorporaler Radium- und Mesothoriumtherapie. *Strahlentherapie,* 1920, *11,* 20–34.
31. Fürstenau, R. Ueber die Verwendbarkeit des Selens zu Röntgenstrahlenenergiemessungen. *Physik. Ztschr.*, 1915, *16,* 276.
32. Glasser, Otto. Wilhelm Conrad Röntgen and the Early History of the Roentgen Rays. Charles C Thomas, Springfield, Ill., 1934, pp. 408, 414.
33. Glasser, O., and Portmann, U. V. Standardization of the roentgen-ray dose. Am. J. Roentgenol. & Rad. Therapy, 1928, *19,* 47–61.
34. Glasser, O., Portmann, U. V., and Seitz, V. B. Condenser dosimeter and its use in measuring radiation over a wide range of wave lengths. Am. J. Roentgenol. & Rad. Therapy, 1928, *20,* 505–513.
35. Glasser, O., Quimby, E. H., Taylor, L. S., and Weatherwax, J. L. Physical Foundations of Radiology. Paul B. Hoeber, New York, 1944.
36. Glasser, O., and Victoreen, J. The thimble ionization chamber. *Radiology,* 1937, *29,* 341–351.
37. Glocker, R., Rothacker, O., and Schönleber, W. Neue Methoden zur Messung der Tiefendosis im Wasserphantom. *Strahlentherapie,* 1923, *14,* 389–422.
38. Gray, L. H., Ellis, F., Fairchild, G. C., and Paterson, Edith. Dosage-rate in radiotherapy; symposium. *Brit. J. Radiol.*, 1944, *17,* 327–342.
39. Guilleminot, H. Nouveau quantitometer pour rayons X. *Compt. rend. Acad. d. sc.*, 1907, *145,* 711.
40. Hampson, W. Radiometer for measuring shortened x-rays in body cavities. *Brit. J. Radiol.*, 1911, *16,* 235.
41. Henshaw, P. S., and Francis, D. S. Biological measurement of radiation quantities. Am. J. Roentgenol. & Rad. Therapy, 1938, *40,* 906–912.
42. Henshaw, P. S., Henshaw, C. T., and Francis, D. S. Effect of roentgen rays on the time of the first cleavage in marine invertebrate eggs; differential recovery and its influence when different methods of exposure are used. *Radiology,* 1933, *21,* 533–541.
43. Henshaw, P. S., Henshaw, C. T., and Francis, D. S. Relative effects produced by 200 kv. roentgen rays, 700 kv. roentgen rays and gamma rays; comparison based on effects on *Drosophila* eggs and on wheat seedlings. Am. J. Roentgenol. & Rad. Therapy, 1933, *29,* 326–333.
44. Holthusen, H. Ueber die Beziehungen zwischen physikalischer und biologischer Dosimetrie. *Strahlentherapie,* 1924, *17,* 49–68.

45. Holthusen, H., and Gollwitzer, H. Die Qualitätsmessung der Röntgenstrahlen in der Tiefentherapie. *Strahlentherapie*, 1927, *26*, 101–119.
46. Holzknecht, G. Ueber das Chromoradiometer. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1902–1903, *6*, 49; 102.
47. Holzknecht. Weitere Mitteilungen über die Skala zum Sabouraud. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1910, *15*, 372–376.
48. Jüngling, O. Die praktische Verwendbarkeit der Wurzelreaktion von Vicia Faba Equina zur Bestimmung der biologischen Wertigkeit der Röntgenstrahlen. *München. med. Wchnschr.*, 1920, *67*, 1141–1144.
49. Kassabian, M. K. A resume of the radiometric dosage of the roentgen therapy. Am. Quart. Roentgenol., 1906–1907, *1*, No. 3, 14–34.
50. Kienböck, R. Ueber Dosimeter und das quantimetrische Verfahren. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1905–1906, *9*, 276–295.
51. Kienböck, R. Ueber die Arten der photochemischen Radiometer für Messung des Röntgenlichtes. *Strahlentherapie*, 1913, *2*, 556–567.
52. Kirstein. Zur Frage der direkten Dosimetrie. *Strahlentherapie*, 1914, *4*, 788–793.
53. Klingelfuss, F. Das Sklerometer, seine physikalischen Grundlagen und seine Verwendung bei der Röntgenstrahlen-Therapie. *Strahlentherapie*, 1913, *3*, 772–838.
54. Kolde, W. Experimentelle Untersuchungen über die Tiefenwirkung der Röntgenstrahlen. *Strahlentherapie*, 1913, *2*, 710–713.
55. Krönig, B., and Friedrich, W. Physikalische und biologische Grundlagen der Strahlentherapie. Urban und Schwarzenberg, Berlin, 1918. Also, The Principles of Physics and Biology of Radiation Therapy. English edition . . . appendix by Henry Schmitz. Rebman Co., New York, 1922.
56. Küstner, H. Die Standardisierung der Röntgendosismessung. *Strahlentherapie*, 1924, *17*, 1–48.
57. Lamerton, L. F. Physical investigation of the radiation from a low-voltage x-ray tube (cautery technique). *Brit. J. Radiol.*, 1940, *13*, 136–146.
58. Lindrum, W. Die Beziehungen zwischen Oberflächen- und Tiefenwirkung harter Röntgenstrahlen ohne und mit Benutzung von Filtern. *Strahlentherapie*, 1913, *2*, 293–313.
59. Lorenz, E., and Rajewsky, B. Das Problem der Intensitäts-verteilung im durchstrahlten medium. *Strahlentherapie*, 1925, *20*, 581–631.
60. MacComb, W. S., and Quimby, Edith H. Rate of recovery of human skin from effects of hard or soft roentgen rays or gamma rays. *Radiology*, 1936, *27*, 196–207.
61. MacKee, G. M. X-Rays and Radium in the Treatment of Diseases of the Skin. Second edition. Lea & Febiger, Philadelphia, 1927.
62. Mayneord, W. V. Energy absorption. *Brit. J. Radiol.*, 1940, *13*, 235–247.
63. Mayneord, W. V., and Clarkson, J. R. Energy absorption II. Integral dose when the whole body is irradiated. *Brit. J. Radiol.*, 1944, *17*, 151–157; 177–182.
64. Mayneord, W. V., and Lamerton, L. F. Survey of depth dose data. *Brit. J. Radiol.*, 1941, *14*, 255–264.
65. Mayneord, W. V., and Roberts, J. E. The "quality" of high voltage radiations I. *Brit. J. Radiol.*, 1935, *8*, 341–364.
66. Meyer, W. H., and Braestrup, C. B. Quality determination of roentgen rays. *Radiology*, 1928, *11*, 72–77.
67. Packard, C. Biological measurement of high voltage radiations. *Radiology*, 1940, *34*, 17–23.
68. Perthes, G. Versuch einer Bestimmung der Durchlässigkeit menschlicher Gewebe für Röntgenstrahlen mit Rüchsicht auf die Bedeutung der Durchlössigkeit der Gewebe für die Radiotherapie. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1904–1905, *8*, 12–25.
69. Pfahler, G. E. Roentgen ray filter, and a universal diaphragm and protecting screen. *Tr. Am. Roentg. Ray Soc.*, 1906, p. 217.
70. Phillips, R., and Innes, G. S. Physical measurements in high voltage x-ray therapy. *Brit. J. Radiol.*, 1938, *11*, 498–503.
71. Quimby, Edith H. Comparison of practical methods of measuring roentgen-ray quality for therapy. Am. J. Roentgenol. & Rad. Therapy, 1929, *21*, 64–72.
72. Quimby, Edith H., and Focht, Elizabeth. Preliminary studies on dosage measurements with million volt roentgen rays. Part I and Part II. Am. J. Roentgenol. & Rad. Therapy, 1941, *46*, 376–399.
73. Quimby, Edith H., and Focht, Elizabeth F. Dosage measurements in contact roentgen therapy. Am. J. Roentgenol. & Rad. Therapy, 1943, *50*, 653–668.
74. Quimby, Edith H., and MacComb, W. S. Further studies on rate of recovery of human skin from the effects of roentgen- or gamma-ray irradiation. *Radiology*, 1937, *29*, 305–312.
75. Quimby, Edith H., Marinelli, L. D., and Farrow, J. H. Study of back-scatter. Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 799–815.
76. Quimby, Edith H., and McNattin, R. F. Change in quality of roentgen rays on passing through tissue. Am. J. Roentgenol. & Rad. Therapy, 1932, *28*, 236–244.

77. Recommendations of the International Committee for Radiological Units (Chicago, 1937). *Radiology*, 1937, *29*, 634–636. Also, Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 295–298.
78. Regaud, C., and Nogier, T. Die Einwirkung hoher X-Strahlen-Dosen, welche durch Filtration durch eine 3 und 4 mm. dicke Aluminiumschicht gehärtet werden, auf die Haut und ihre Anwendung in der Röntgentherapie. *Strahlentherapie*, *1913*, *2*, 733–787.
79. Reisner, A. Hauterythem und Röntgenstrahlung. *Ergebn. d. med. Strahlenforsch.*, 1933, *6*, 1–60.
80. Rutherford, E., and McClung, R. K. Energy of Roentgen and Becquerel rays and the energy required to produce an ion in gases. *Proc. Roy. Soc.*, 1901, *67*, 254.
81. Sabouraud, R., and Noiré, H. Traitement des teignes tondantes pas les rayons X à l'Ecole Lailler (Hôpital St.-Louis). *Presse méd.*, 1904, *2*, 825–827.
82. Seemann, H. Die Qualität der Röntgenstrahlen und ihre spektrographische Messung in der Therapie und Röntgentechnik. *Strahlentherapie*, 1924, *17*, 69–112.
83. Shearer, J. S. Measurements with the Coolidge tube. Am. J. Roentgenol., 1914–1915, *2*, 507–514.
84. Shearer, J. S. Physical aspect of roentgen ray measurement and dosage. Am. J. Roentgenol., 1916, *3*, 298–308.
85. Shearer, J. S. United States Army X-ray Manual. Paul B. Hoeber, New York, 1918.
86. Sievert, R. M. Eine einfache zuverlässige Vorrichtung zum Messen von Tiefendosen. *Acta radiol.*, 1926, *5*, 468–470.
87. Solomon, I. Les unités quantitométriques en roentgen-thérapie. *J. de radiol. et d'électrol.*, 1924, *8*, 351–356.
88. Solomon, I. Sur la nécessité de la standardisation des chambres d'ionisation utilisées en dosimétrie radiologique. *J. de radiol. et d'électrol.*, 1927, *11*, 286–290.
89. Stahel, E. Bestimmung der bei Gamma- und Röntgenstrahlbehandlung vom Gewebe absorbierten Energiemengen. *Strahlentherapie*, 1929, *33*, 296–321.
90. Stenstrom, W. Consideration of body dose in radiation therapy. *J. Cancer Research*, 1924, *8*, 30–33.
91. Stern, S. Method for measuring the quantity of x-ray. *J. Cutan. Dis. incl. Syp.*, 1903, *21*, 568–570.
92. Szilard, B. On the absolute measurement of the biological action of X-rays and gamma rays. *Arch. Roentg. Ray*, 1914–1915, *19*, 3–20.
93. Szilard. B. Ueber die absolute Messung der Röntgen und γ-Strahlen in der Biologie. *Strahlentherapie*, 1915, *5*, 742–771.
94. Taylor, L. S. Recent progress in x-ray standardization. *Radiology*, 1931, *16*, 1–13.
95. Taylor, L. S. International comparison of x-ray standards. *Radiology*, 1932, *18*, 99–114.
96. Taylor, L. S. Time factors in the ionization of carbon disulphide by x-rays. *J. Research Nat. Bur. Standards*, 1936, *17*, 557.
97. Taylor, L. S., and Singer, G. Standard absorption curves for specifying the quality of x-radiation. *Radiology*, 1934, *22*, 445–460.
98. Villard, M. P. Radiosclérometre. *Arch. d'électric. méd.*, 1908, *16*, 236.
99. Villard, M. P. Instruments de mesure à lecture directe pour les rayons X. *Arch. d'électric. méd.*, 1908, *16*, 692.
100. Weatherwax, J., Bradley, R. A., Bowen, D. R., and Leddy, E. T. Convenient and accurate method of measuring roentgen-ray depth dosage. Am. J. Roentgenol. & Rad. Therapy, 1926, *15*, 169–174.
101. Williams, E. G. Regulation of the duration of exposure and the distance from the tube in x-ray therapy. *Tr. South. Surg. & Gynec. Ass.*, 1903, Philadelphia, 1904, *16*, 389–392. Also, *Med. News*, 1904, *84*, 592.
102. Wintz, H., and Rump, W. Das Röntgenphotometer. *Strahlentherapie*, 1926, *22*, 444–459.
103. Wood, F. C. Biological ionization chamber. *Radiology*, 1929, *12*, 461–471.

UTILIZATION OF ANTIBODY FOR THE LOCALIZATION OF METALS AND DYES IN THE TISSUES

PRELIMINARY REPORT

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THE antigen-antibody reaction and the properties of antibody under various conditions have been studied extensively. The outstanding characteristic of antibody is that when it unites with an antigen it does so specifically. In this paper we present experimental evidence that this specificity can be utilized to transport metals and dyes which have been combined with antibody, to predetermined sites in the tissues. Details of the method used to form the metal or dye antibody combinations will be described in another publication.

EXPERIMENTAL

Experiment No. 1. Localization of Heavy Metal by Means of Antibody (Pneumococcus Type I). A control roentgenogram (Fig. 1*A*) was made of the pelvis and hind legs of a 450 gram guinea pig after the right thigh of the animal was infiltrated with 10 milligrams of pneumococcus polysaccharide, Type I, suspended in 0.5 cc. of normal saline, and the left thigh was infiltrated in the same way with 10 milligrams pneumococcus polysaccharide, Type II. The left femoral vein was then exposed and 2.0 cc. of pneumococcus antibody, Type I, combined with approximately 60 milligrams of uranium was injected intravenously. The animal died about twenty minutes after the injection of this material. A roentgenogram was then made (Fig. 1*B*). It showed a striking deposition of metal in the soft tissues of the right thigh at the site where the muscle was infiltrated with pneumococcus polysaccharide, Type I. None appeared on the opposite side where the Type II pneumococcus polysaccharide was injected.

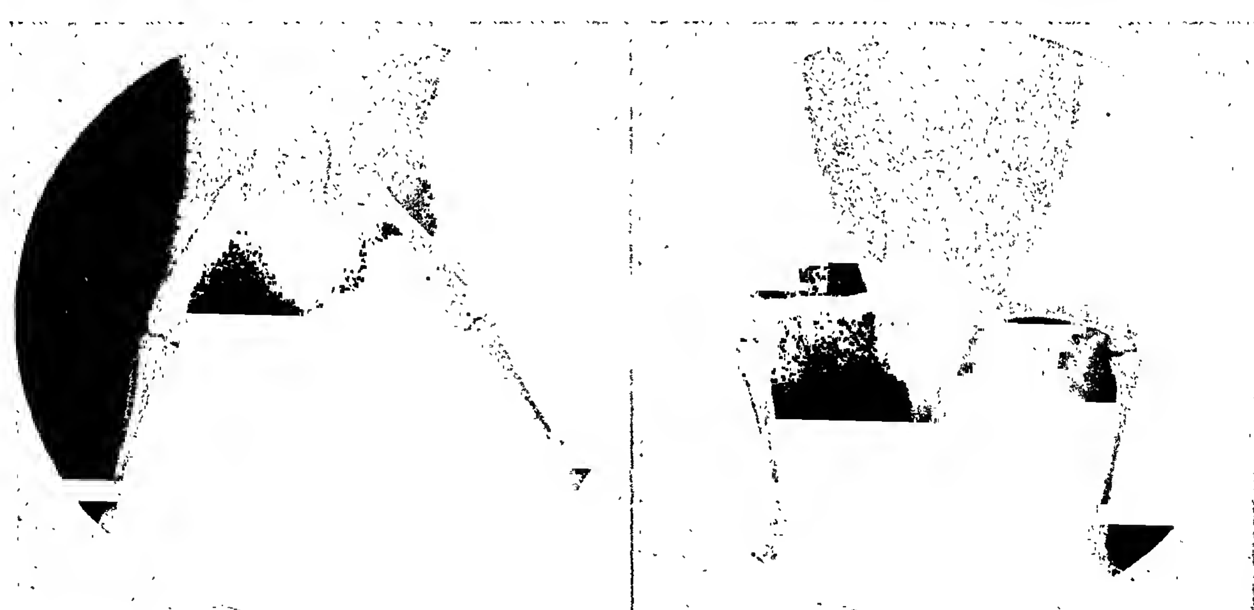
Experiment No. 2. Localization of a Heavy Metal by Means of Antibody (Pneumococcus Type II). This experiment was similar to No. 1 except that pneumococcus antibody, Type II, containing approximately 60 milligrams of uranium was substituted for pneumococcus antibody, Type I. A preliminary roentgenogram of the pelvis and hind legs of the guinea pig was made (Fig. 2*A*) after the right thigh of this animal was infiltrated with 4.0 milligrams of pneumococcus polysaccharide, Type I, and the left thigh was infiltrated with 4.0 milligrams of pneumococcus polysaccharide, Type II, suspended in 0.5 cc. of normal saline. Two cubic centimeters of pneumococcus antibody, Type II, combined with approximately 60 milligrams of uranium was injected into the right femoral vein. The animal died in about twenty minutes. A roentgenogram (Fig. 2*B*) disclosed a deposition of uranium in the left thigh at the site where the muscle had been infiltrated with pneumococcus polysaccharide, Type II. None appeared on the opposite side where Type I pneumococcus polysaccharide was injected.

Experiment No. 3. Localization of Dye by Means of Antibody. Malachite green was combined with purified pneumococcus antibody, Type II, to form an antibody dye combination. A guinea pig weighing 300 grams was used as a control. Two cubic centimeters of pneumococcus antibody, Type II, combined with the dye was injected into the femoral vein. The left lung was then infiltrated through the chest wall with 10 milligrams of pneumococcus polysaccharide, Type I. The animal was destroyed in about ten minutes. Examination of the lungs disclosed no discoloration other than small hemorrhagic areas caused by the injection needle. Microscopically, only traces of the dye were seen in the pulmonary capillaries. The experimental guinea pig weighed about 300 grams. As in the control experiment 2.0 cc. of pneumococcus antibody, Type II, combined with the dye was injected into the femoral vein. Pneumococcus polysaccharide, Type II, was then injected through the chest wall into the left lung. The animal died in about ten minutes. Examination of the lungs showed a gross greenish discoloration on the left side. A smaller amount of discoloration was also seen in the right lung. Microscopically, large aggregates of colored precipitate were seen in the vessels occluding many of the capillaries.

A B

FIG. 1*A*. Control roentgenogram of pelvis and hind legs of a guinea pig made after infiltration of right thigh with pneumococcus polysaccharide, Type I, and left thigh with pneumococcus polysaccharide, Type II.

FIG. 1*B*. Roentgenogram of pelvis and hind legs of a guinea pig following the intravenous injection of pneumococcus antibody, Type I, combined with uranium. This shows a deposition of metal in the soft tissues of the right thigh at the site of the injection of specific antigen pneumococcus polysaccharide, Type I. None appeared in the left thigh where the Type II pneumococcus polysaccharide was injected.



A B

FIG. 2*A*. Control roentgenogram of pelvis and hind legs of a guinea pig made after infiltration of right thigh with pneumococcus polysaccharide, Type I, and left thigh with pneumococcus polysaccharide, Type II.

FIG. 2*B*. Roentgenogram of pelvis and hind legs of guinea pig following the intravenous injection of pneumococcus antibody, Type II, combined with uranium. This shows a deposition of metal in the soft tissues of the left thigh at the site of the injection of specific antigen pneumococcus polysaccharide, Type II. None appeared in the right thigh where the Type I pneumococcus polysaccharide was injected.

COMMENT

These experiments were repeated a number of times with similar results. The deposition of dye in the lung and metal in the soft tissues at the sites of specific antigen was unmistakable and took place within a few minutes after injection. It can be presumed, therefore, that the metal or dye remained firmly bound to antibody in the blood stream and that the specificity of antibody had not been materially altered by the combination. In view of the complex nature of the antibody-antigen reaction, the stability of the metal and dye antibody combinations is striking.

Purified pneumococcus antibody, uranium and malachite green were used in these antigen-antibody reactions. However, similar combinations can be made with other materials. We have combined other antibody and metals in the same way without materially altering their immunological specificity. Examples of this, details of which will be reported later, were combinations of radium F (polonium) with antibody against lymphocytoma, adenocarcinoma of the breast, and pneumococcus antibody, Type I and Type II. These experiments suggest a procedure whereby uniform radiation can be applied selectively to certain tissues.

SUMMARY

1. Experimental evidence has been presented to show that under certain conditions purified antibody can be combined with metals and dyes without altering its essential immunologic specificity.

2. Utilization of antibody for the localization of metals and dye in the soft tissues of animals has been demonstrated.

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SALIENT FACTORS IN THE TREATMENT OF HODGKIN'S DISEASE AND LYMPHO-SARCOMA WITH ROENTGEN RAYS

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HISTORICAL CONSIDERATIONS

WHEN, late in December, 1895, Röntgen announced his discovery of the rays which, because he did not know their character, he chose to call "x-rays," this announcement made a tremendous sensation throughout the world. Perhaps the best account of the discovery was written by H. J. W. Dam and was published in the April, 1896, number of *McClure's Magazine* which, at that time, was one of the outstanding periodicals of this country. Within a few months, professors of physics and many others began to produce these rays by means of Ruhmkorff induction coils and Crookes tubes, and the new rays were soon being used to examine fractures and dislocations of bones, to record the situation of foreign bodies, and also to determine whether or not the rays might have a favorable influence on certain pathologic processes.

As early as 1896, an interesting example of the favorable effect of the rays was reported by Despeignes in *Lyon médical* (France). This was the case of a man, aged fifty-two, whose health had been deteriorating for some time and who was thought to be afflicted with cancer of the stomach. After various other forms of treatment had failed to influence the patient's condition, the idea of trying roentgen rays was considered. Beginning on July 4, 1896, two exposures, each of half an hour, were given daily for eight days to a single abdominal field. To the amazement and delight of all concerned, this treatment was followed by rapid relief from pain, and the size of the tumor diminished progressively. However, the patient's condition continued to improve for only a short time, when it again deteriorated, and he died on July 23, 1896. A point of great interest was that the abdominal tumor had continued to diminish until, at the time of his death, it could no longer be felt. Because, after the exposures to roentgen rays, the patient had been given injections of an "artificial serum" (Dr. Cheron's formula), Despeignes assumed that perhaps these injections had been responsible for the abatement of the pain, but he could not thus account for the reduction in size of the tumor, and he was greatly puzzled.

A review of this early case report makes it seem more than likely that, considering the physical quality of the rays generated by the apparatus available at that time, or even without considering this factor, the patient could not have suffered from carcinoma of the stomach. An epithelial tumor could not have been influenced so rapidly or so much by treatment of this kind. The abdominal neoplasm—assuming that it was a neoplasm—must have been exceptionally sensitive to roentgen rays. At that time the comparative sensitiveness of different kinds of cells to roentgen rays was not known, but our present knowledge, which is based on a large body of experimental evidence and on extended clinical observation, makes it almost certain that, in view of the history of the patient's illness, he must have been suffering from a form of lymphoblastoma (Hodgkin's disease or lymphosarcoma) of the retroabdominal (para-aortic) lymph nodes, with or without secondary involvement of the stomach. Only a condition such as this could have been affected so rapidly and so favorably by the rays. But, from the history of the case and from the large size

of the tumor, it is obvious that the malignant process had reached an advanced stage, when treatment of any kind could not be expected to stay its course for more than a short time.

GENERAL CONSIDERATIONS

The tremendous and widespread influence of habit is often astonishing. Most of us are aware of this influence on physical action or behavior, and we know how difficult it often is to break some of these habits. What is not so generally recognized is the influence of habit on thinking, and it is precisely because of our failure to recognize this influence that habits of thought, of which, as often as not, we are not even aware, are so difficult to break.

For many years—and it is more true today than ever before—it has become a habit or fashion to treat every kind of malignant tumor essentially by the same method. Thus, in general, carcinomas or epitheliomas, fibrosarcomas, chondrosarcomas, lymphoblastomas and so forth, are treated with rays generated at 200, 400, 600, or even 1,000 kv., and filtered through 0.5, 0.75, 1.0, 2.0 or more millimeters of copper or zinc, but sometimes part of the filter may consist of a certain thickness of tin, and the treatment usually is given by the fractional method or by some modification of it. Commonly the aim is to deliver to the tumor or tumors the largest total dose which can be given without producing irreparable damage to the normal tissues.

Why has this basic method been so widely adopted? After all, methods of treatment do not fall ready-made from heaven but are based on certain lines of thinking. The principal factors are: (1) the well founded idea that rays of different wave lengths act on cells and tissues in the same way, although the degree of their action varies with the quantity of rays received by the cells; (2) the concept of "depth dose," according to which the greater the quantity of rays which penetrates the body to a depth of, let us say, 10 cm., the greater must be the action of the rays on the tumor; (3) the more penetrating the rays (the greater the depth dose), the less danger there is of injuring the skin; (4) the experiments of Regaud and his co-workers, which had shown that, when a given area is exposed to a small dose daily for a long time, a much larger total dose can be given without serious injury, and (5) the experiments of Wood and Prime, which had proved that it takes from five to eight times an erythema dose completely to arrest the growth of an epithelioma or carcinoma.

There is no doubt that the main reason why the first two of the factors which I have mentioned have had, and still have, such a widespread influence on roentgen treatment has been the teaching of physicists who have justly stressed these points. The third factor has come from the universal desire, on the part of radiologists, to avoid serious injury to the skin and the lawsuits which sometimes follow.

Physics is an important phase of therapeutic radiology but, as I shall attempt to bring out later, treatment based entirely on physical factors may not always yield the most favorable results. Cellular biology also is an important phase of therapeutic radiology, but too often it does not receive as much attention as it deserves. It is certain that, when a radiologist allows himself to be so completely submerged by physical considerations that he overlooks the biologic factors, the results which he obtains may not be as good as they might be.

No one can question the experimental results obtained by Regaud and his collaborators[9–21] or those obtained by Wood and Prime. Long application of these results by many radiologists throughout the world have fully confirmed their validity as far as epithelial neoplasms are concerned, and they are also applicable to other varieties of neoplasms which have an equal or greater resistance to roentgen rays. But, when we have to deal with tumors composed mainly of cells which are much more sensitive to the rays than

epithelial cells, the validity of the principles established by Regaud and by Wood and Prime may be seriously questioned, and the applicability of the other physical factors which I have mentioned may also be questioned.

This is especially true of tumors derived from lymphoid cells which, as is well known, are exceptionally sensitive to roentgen rays. Elsewhere I have ventured to list the different varieties of normal cells in the order of their sensitiveness to roentgen rays,[1] and I have also attempted to give an approximate classification of neoplasms according to their sensitiveness.[2] Even a casual glance at these classifications is sufficient to make one realize that the sensitiveness of tumors agrees closely with that of the variety of normal cell of which each kind of tumor is mainly composed. If this is true—and a large body of experimental evidence and prolonged clinical observation has removed all doubt on this point—then it must be clear that the close agreement between the sensitiveness of any variety of cells and that of tumors derived from these cells cannot possibly be a result of coincidence. Thus the sensitiveness of tumors derived from lymphoid cells, such as the tumors which characterize Hodgkin's disease and lymphosarcoma, corresponds so closely to the sensitiveness of normal lymphoid cells (lymphocytes) in lymph nodes, in the circulating blood, in the spleen, in solitary lymph follicles in the intestine and in all other aggregations of lymphoid cells that it would be well nigh impossible to doubt that these cells are identical in both cases.

So important are these points that a radiologist who is thoroughly familiar with the relative sensitiveness of different kinds of cells and tumors can often make use of this knowledge to distinguish one variety of neoplasm from another, and in certain cases in which the opinion of a pathologist may conflict with the history of the patients' illnesses, with their clinical features, or with the effect of roentgen treatment, the effect of treatment may be more important than the unsupported opinion of the pathologist. Best of all, of course, is a critical correlation of all these elements.

How sensitive are the lymphoid cells? Among the many investigations on animals let us take only a few outstanding ones. First were those of Heineke,[6–8] who, after exposing to roentgen rays the entire body of a large number of mice, found, in all the mice which had thus been exposed, a rapid destruction of lymphocytes in the lymph nodes, spleen, circulating blood and other collections of lymphoid cells. These experiments—and many others which were made—showed that lymphocytes are more sensitive than all other cells, but they did not give an accurate idea of the extreme sensitiveness of these cells. Warthin undertook to study this problem further, and the importance of his experiments rests on the fact that he arranged his technique in such a way that sections of lymph nodes and other lymphoid structures could be obtained and could be examined microscopically within half an hour, and sometimes within fifteen minutes, after the animals had been exposed to the rays. Even after such a short time, he observed some destruction of lymphocytes. Under these circumstances, one can hardly speak of a latent period. When cellular destruction can be recognized through a microscope within fifteen or thirty minutes, the effect of the rays on the cells must have started during exposure.

Interesting as are these experiments of Warthin because they show how sensitive these leukocytes are, they do not give an absolute measure of the extreme degree of their sensitiveness. Other experiments have been carried out at two well known universities in this country during the past few years but, to my knowledge, the results have not yet been published (personal communications). One series of experiments showed that a surface dose of 15 roentgens is sufficient to cause perceptible destruction of lymphoid cells in lymph nodes. In the second of these investigations it was found that a dose of 10 roentgens

is sufficient to destroy some of these cells. Further comment is hardly necessary.

What does all this have to do with roentgen treatment of Hodgkin's disease or lymphosarcoma?

CLINICAL CONSIDERATIONS

The most essential point in treating patients who are afflicted with Hodgkin's disease or lymphosarcoma is a sound knowledge of the clinical features of these conditions, and the greater this knowledge the better.

Hodgkin's disease and lymphosarcoma are more common than earlier writers have led us to believe. This is probably because these conditions begin so insidiously; because, in the past, they were often mistaken for other conditions, such as tuberculous adenitis, and because, even now, in some cases the disease is not recognized until the pathologic process has reached a rather advanced stage. Another reason is that too much attention has been concentrated on the lymph nodes in the neck, armpits and groins.

In a considerable proportion of cases these forms of lymphoblastoma begin in the cervical nodes and thence extend to other groups of nodes. In some cases they begin in the nasopharynx, nasal accessory sinuses or tonsils. When the structures mentioned are involved, it is often assumed that the malignant process began there but, as often as not, the process may have been active in other parts of the body, notably in the retro-abdominal nodes, long before secondary invasion of structures in the head or neck developed. Therefore, when the nasopharynx, accessory sinuses, tonsils, or cervical lymph nodes are affected, this may be the primary site of the pathologic process, but it may represent secondary involvement.

The rapidity with which the cervical nodes enlarge and the size which they attain vary greatly in different cases. At the beginning and sometimes for long periods (several months or several years), the affected nodes enlarge for a time and then recede, and this cycle may be repeated indefinitely. Many patients are abnormally subject to infections of the upper respiratory tract; after each infection of this kind, the affected lymph nodes tend to enlarge for a time and then to recede again. When this occurs, patients often think the nodes have disappeared; usually they have not disappeared but they have diminished in size until the patients are no longer aware of their presence. As these cycles tend to recur from time to time, the size of the affected nodes tends gradually to increase. In some cases they may remain small for a long time, and then, for some obscure reason, they begin to enlarge and may reach considerable proportions in a short time. The cervical nodes may thus attain the size of olives, of plums, or even of lemons. In other cases they never become so large and in certain cases they remain small throughout the course of the malignant process. The mere size of the nodes does not give any indication of the degree of malignancy or of the seriousness of the patient's condition. This is true, not only of the cervical nodes, but of lymph nodes in any other region.

Mediastinal Nodes. As far as the lymph nodes in the thorax are concerned, those in the mediastinum (right and left paratracheal nodes and tracheobronchial nodes or both) are most commonly involved. However, Hodgkin's disease or lymphosarcoma begins in the mediastinal nodes much less commonly than it begins in the head, neck or retro-abdominal nodes. In most cases, when the mediastinal nodes are invaded, the involvement of these nodes is secondary to similar, but earlier, involvement of lymph nodes in other regions.

When Hodgkin's disease or lymphosarcoma involves the mediastinal nodes, a roentgenogram of the thorax usually reveals a bilateral and roughly parallel widening of the mediastinal structures, which extends from the inlet of the thorax downward to the cardiac shadow, which it usually overlaps more or less. But excep-

tions are not uncommon. Sometimes the nodes mainly affected are in one side or the other of the mediastinum, and the roentgenologic appearance may make it difficult to be certain whether the lesion is lymphoblastomatous or carcinomatous, a teratoma, a neurofibroma, or perhaps a dermoid tumor. Sometimes, enlargement of mediastinal nodes may be bilateral and ovoid in shape, and again the distinction between lymphoblastoma and carcinoma or some other tumor cannot be made with certainty from the roentgenologic appearances alone. In some cases the lymphoblastomatous character of the lesion can be recognized by other clinical features, such as enlargement of nodes in the neck or armpits, with or without involvement of the retroperitoneal and inguinal nodes. In other cases, however, such associated features may not be present. Then it is that irradiation of the mediastinum may, by causing a characteristically rapid regression, not only relieve the patient's symptoms but give a reliable clue to the pathologic character of the tumor.

Occasionally, the principal involvement is high in the mediastinum, and the symptoms may include not only dyspnea, with or without dysphagia, but also a brassy cough, hoarseness from involvement of one or both recurrent laryngeal nerves, puffiness and semicyanosis of the neck and face, and prominence of the superficial veins due to venous obstruction at or near the inlet of the thorax. The cervical nodes also may be abnormally large but, owing to the puffiness and engorgement, they may be difficult to perceive with certainty. The physician who is "thyroid conscious" may think that the roentgenogram suggests substernal extension of the thyroid, but the prompt regression of the growth and relief of the symptoms during and after irradiation may show this also to have been essentially lymphoid in character.

In some cases of mediastinal lymphoblastoma, roentgenograms of the thorax show little, if any, widening of the mediastinal shadow, and yet the symptoms suggest more or less definite involvement of the tracheobronchial nodes situated in and around the angle of the tracheal bifurcation. The reason the roentgenograms do not show lateral projection beyond the edges of the composite shadow cast by the sternum and spinal column may be that the affected lymph nodes have an anteroposterior disposition.

Pleural effusion may be caused by partial obstruction of the inferior vena cava by enlarged nodes in the lower part of the mediastinum; because the adenopathy is concealed by the cardiac shadow, it may not be visible in roentgenograms. Or the effusion may be due to infiltration of the pleura. In such cases, effective irradiation requires that the fields be large enough to include the lower two-thirds of the mediastinum as well as the entire diaphragm. Involvement of this kind, however, usually occurs only when the pathologic process has reached a relatively advanced stage, and prolonged improvement can hardly be expected under these circumstances.

Rarely, Hodgkin's disease or lymphosarcoma may infiltrate the lungs in what approximates a miliary manner. That is, the infiltration is scattered more or less throughout the lungs in the form of small almost miliary foci. Infiltration of this kind indicates that lymphoblastoma has invaded most or all of the small aggregations of lymphoid cells situated at the junction of the smaller branches of the bronchi. This form of infiltration also is a relatively late complication. Nevertheless, thorough irradiation may result in pronounced improvement; the duration of improvement varies with the circumstances in each case.

Sometimes, when lymphoblastoma affects the mediastinal nodes, the patient complains of pain in the thorax, which may extend to one or both upper extremities. Occasionally, the pain may be confined to the extremities, and pain in the thorax may not be present. Roentgenograms may show obvious or even marked

involvement of the nodes, but in some instances evidence of mediastinal involvement may be slight or actually uncertain. Under these circumstances, it is important to exclude, by careful examination, the possibility that the pain may be due to pressure irritation or actual infiltration of branches of the brachial plexus on one or both sides by lymphoblastoma affecting some of the cervical nodes or nodes in the upper part of the axillary (infraclavicular) space. If this possibility can be excluded, then the treatment should be directed to the mediastinum, as already suggested.

By physical examination alone, as most physicians know, it is often difficult or impossible to recognize intrathoracic involvement in these conditions; even when roentgenoscopy or roentgenography is employed, it may be impossible to distinguish Hodgkin's disease or lymphosarcoma from other neoplastic processes, such as carcinoma, neurofibroma, fibrosarcoma, teratoma, dermoid cyst, thymoma or the so-called Pancoast tumor. This is especially true during the early stage, but it is often true at any stage. One reason for this difficulty is that different kinds of tumors in the thorax can grow in such a way as to produce very similar roentgenologic signs. While, in most cases, Hodgkin's disease or lymphosarcoma involves nodes in both sides of the mediastinum and, consequently, produces a bilateral shadow which usually is nodular, lobular and more or less typical, it is not rare for these conditions to involve the nodes in one side much more than those in the other side, or even, as far as roentgenologic appearances go, the involvement may appear to be confined to the nodes in one side of this region. Sometimes, either in their original form or by some of the peculiar vagaries which may arise during their course, these forms of lymphoblastoma can simulate many other malignant neoplasms as well as some inflammatory conditions.

Retroperitoneal Nodes. Lymphoblastoma begins in the retroperitoneal nodes much more frequently than is generally supposed. but even when this form of malignant growth begins in the cervical or mediastinal nodes, or elsewhere, it often extends sooner or later to the retroperitoneal nodes. In 1939 I[3] drew attention to the clinical importance of these nodes and to the great variety of symptoms which their involvement in Hodgkin's disease and lymphosarcoma can cause.

When the para-aortic or mesenteric nodes become affected by lymphoblastoma, the symptoms at first and for some time may be so slight and vague that their recognition is difficult. Moreover, they vary considerably in different cases. These symptoms may consist of a tendency to bloat and belch after eating, distress in the upper half of the abdomen after meals, and loss of strength, which patients usually express as tiring easily, loss of endurance, or loss of "pep." As months or years elapse these symptoms tend gradually to increase, and others develop. The latter may include a sense of heaviness or of weight in the epigastrium, especially after eating, increasing difficulty in eating a full meal; pain in the epigastrium, which may recur after each meal; an increasing tendency toward constipation; pain in the lower thoracic, lumbar or sacral portions of the back, often extending to one or both hips or down one or both lower extremities; fever occurring in periodic bouts at varying intervals or continuing steadily, although with variations in intensity; regional and later general itching, with or without cutaneous lesions, which may be mistaken for urticaria, impetigo, scabies and so on. I shall not discuss these symptoms further except to mention that they may occur in different combinations and that some of them represent absolute signs that the retroperitoneal nodes have become involved.

When a patient is known to have Hodgkin's disease or lymphosarcoma, fever or itching, or both, mean that the condition has invaded the retroperitoneal nodes. A combination of two or more of the other

symptoms mentioned may mean the same thing, but the evidence is not so conclusive. Proof of the foregoing is to be found in the fact that, if the retro-abdominal nodes are properly treated, the fever, itching and cutaneous disturbances, when present, diminish or disappear soon after treatment, unless the pathologic process has reached an advanced stage or has entered the terminal phase. With few exceptions, and then never to the same degree, this effect is not observed when the treatment is directed toward regions other than the abdomen.

Variation in the abdominal symptoms in different cases probably depends on the particular nodes or group of nodes which are most involved and on the anatomic relationships of these nodes to various abdominal organs or structures. Sometimes lymphoblastoma may affect chiefly the upper para-aortic nodes. These are situated in the region of the celiac axis and are thus immediately behind the stomach, pancreas and duodenum, and in close proximity to the diaphragm or to the mouth of the thoracic duct. It is not surprising, therefore, that when some of these nodes become abnormally large they may give rise to pressure disturbances in any of the structures mentioned. They may crowd the liver and spleen forward and downward. When these nodes enlarge in an upward direction, they may press on the diaphragm and cause dyspnea, or they may interfere to some extent with the action of the heart. Sometimes enlargement is mainly in a posterior direction, causing pressure erosion of some of the lower thoracic vertebrae, or the pathologic process may infiltrate the intervertebral spaces, may thus extend into the spinal canal, and even invade the cord.

In other cases the para-aortic nodes mainly affected are below this level, and the pressure disturbances are most likely to concern branches of the lumbosacral plexus, the small intestine, the colon, the ureters or kidneys, and the lumbar vertebrae. Sometimes the nodes principally involved are lower still; they may be situated around the bifurcation of the great abdominal vessels or along the common iliac vessels. Rarely, the iliac nodes may become large enough to cause pressure erosion of the wing of the ilium. Rarely, also, the nodes mainly affected may be those along the internal iliac vessels; the symptoms may then be referable chiefly to some of the pelvic structures, such as the ureters, bladder or rectum.

As involvement of the retroperitoneal nodes by lymphoblastoma progresses, not only the para-aortic nodes but the mesenteric nodes also may be invaded. Sometimes, in fact, the involvement finally becomes so extensive that practically every structure containing lymphoid tissue is infiltrated more or less. This, of course, is most likely to occur in the late stages.

In order to treat most effectively lymphoblastoma affecting the retroperitoneal nodes, it is important to recognize these different possibilities or probabilities and to arrange the treatment accordingly. When the nodes chiefly affected are those along the abdominal aorta, between the bifurcation and the diaphragm, two large anterior fields, extending from the junction of the ensiform cartilage to the sternum down to just below the level of the umbilicus, and two corresponding posterior fields, are sufficient. But when the involvement includes the iliac and inguinal nodes, four anterior and four posterior fields are required. When, as occasionally happens, the iliac and inguinal nodes are chiefly involved, the treatment is best given through two low anterior and two corresponding posterior fields; in this case the anterior fields should extend well below the inguinal fold, so as to include the nodes in Scarpa's triangle.

Certain exceptions, however, should be considered. When retroperitoneal involvement is minimal or uncertain, or when the general condition is such that ability to tolerate more thorough irradiation seems doubtful, it may be advisable to give only limited treatment so as to bring about improvement without taxing the

patient's tolerance. Later, after the general condition has improved, more thorough treatment can be undertaken. In these cases the first course of treatment may be given through two or four posterior fields only. When the patient is thin or when the contour of the trunk is relatively flat from front to back, the same distribution of fields may be adopted with advantage.

In women aged less than forty years, when evidence of pronounced involvement of the iliac nodes cannot be found, neither the anterior nor the posterior fields should extend below the level of the crest of the ilium. Otherwise, artificial menopause may be induced, and this only adds to the patient's difficulties.

Irradiation of the abdomen tends to influence the leukocytes even more than does irradiation of other parts of the body. Hence, when this region is treated the leukocytes should be watched more closely than ever. At the Mayo Clinic, daily blood counts are the rule when irradiation of the abdomen is employed. As the treatment proceeds, the number of these cells tends to decrease; often this decrease is not steady and considerable fluctuation may be observed from day to day. Sometimes, on account of leukopenia, the treatment may have to be discontinued for one or two days, or abandoned altogether. The leukocyte count may remain abnormally low for periods which may vary from two or three weeks to two or more months, and this may interfere with subsequent treatment. Then the number of these cells tends to increase until it again reaches the normal level. The rapidity with which leukopenia develops, its duration, and the rate of regeneration vary greatly in different cases and depend on a number of factors, such as the stage of the malignant process, the volume of body tissues subjected to treatment, the regions treated, and the dose of radiation given to each field, as well as the total dose. Besides these factors, individual variation plays an important part. Occasionally a patient is encountered in whom leukocytic regeneration is extremely slow or in whom leukopenia may continue indefinitely.

An interesting, and sometimes an important, point to remember is that, when lymph nodes in the axilla are affected by these conditions, the mediastinal nodes also are usually involved. The reverse is often true but this is less common. In some cases involvement of the mediastinal nodes cannot be demonstrated easily because they have not become sufficiently large to project beyond the borders of the sternum and spinal column. Similarly, when the inguinal nodes are affected, it can almost be taken for granted that the retroabdominal (para-aortic, mesenteric or iliac) nodes also are involved. In 1939 I[3] drew a attention to these points, and since then Symmers (1944) has confirmed their validity by extended observations at necropsy.

Unusual Complications. Among the many unusual complications which develop in certain cases of Hodgkin's disease or lymphosarcoma may be mentioned nodular infiltrations of the scalp or skin or diffuse infiltration of subcutaneous tissues in the axilla, breast, or other regions; infiltration of the orbit, of the lids, or of the eyeball itself; extension of the pathologic process from the mediastinal nodes to the subcutaneous tissues over the upper part of the sternum, where it may form a mass the size of a fist or of two fists; infiltration or erosion of a bronchus by adjacent mediastinal nodes; infiltration of a ureter, of the renal pelvis or of the kidney itself, with displacement, dilatation, hematuria, and hydronephrosis or pyelonephritis; infiltration of the suprarenal glands, with increased pigmentation of the skin; infiltration of the cerebral meninges or of the brain, and infiltration of the rectum which may have the form of polyps or which may simulate carcinoma.

Lesions of Bone. Not infrequently, certain bones may undergo destructive changes; this is prone to occur in the spinal column, where, as the result of increasing pressure exerted by enlarging retro-abdominal or mediastinal lymph nodes, one or more

vertebrae may be affected more or less. Similar erosive destruction may occur in the ilium because of the increasing pressure of affected iliac nodes. Sometimes, instead of erosion by pressure, diffuse osteoporosis of the spinal column or of other bones may develop, but the factors which are responsible for the loss of calcium are not understood. Less commonly, destructive changes in a bone may result from extension of the malignant process to the marrow.

The Blood. In many cases the number of erythrocytes and leukocytes is approximately normal. In other cases, especially when the retroperitoneal or mediastinal nodes are affected, the number of leukocytes may increase to 12,000, 15,000, 20,000 per cubic millimeter, or even more. In some cases, on the contrary, the number of leukocytes may diminish to 5,000, 4,000, or even less. In some cases the number of lymphocytes, monocytes, or eosinophils becomes abnormally high. As a rule, the number of erythrocytes remains normal for a long time but, when the malignant process reaches an advanced stage or approaches the terminal phase, some degree of anemia develops and gradually tends to increase until the patient dies. When the pathologic condition reaches an advanced stage, some patients begin to bleed from the nose, from the gums, from the respiratory tract or from the gastrointestinal tract, and some die primarily from hemorrhage.

TREATMENT

Treatment, if it is to yield maximal improvement, must be arranged so as to deal most effectively with the lesions which are responsible for the outstanding symptoms. The patient's chief symptoms should always be given due consideration, but often symptoms which he may regard as minor or as not related to his illness may actually be more important than the presenting symptoms. Before the treatment can be arranged, therefore, the entire situation should be considered as a whole. Treatment should first be directed toward the region of major involvement; this may or may not coincide with the patient's chief symptoms. Then, regions of relatively minor involvement can be treated. When the history of the patient's illness has been carefully and completely recorded, and when it is correlated with the physical and other findings, one should have a good idea of the situation.

Cervical Lymphadenopathy. When the cervical nodes are small or moderate in size, and when the nodes in other regions are not affected, irradiation of a single field on each side of the neck (Fig. 1) may be sufficient. When the involvement is confined to the nodes on one side of the neck, treatment should, of course, be limited to a single field on the affected side.

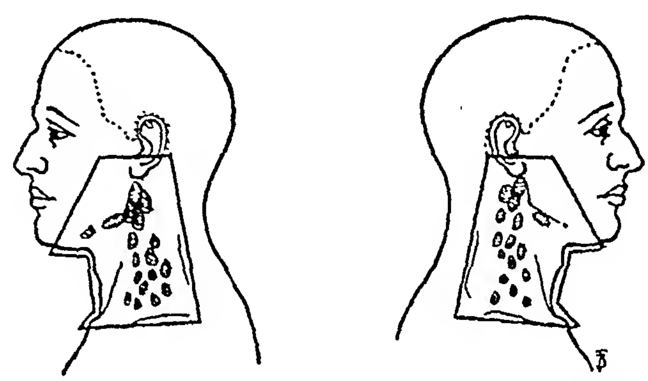

Fig. 1. Fields of roentgen treatment over each side of the neck when the cervical nodes are only slightly or moderately enlarged.

When the lymphadenopathy extends throughout the length of the neck, and especially when the submental, submaxillary, preauricular and postauricular, or occipital, nodes are involved, or when the patient's neck is unusually long, the region may be too large to be included in a single field on each side. In such a case, each side must be divided into two fields (Fig. 2). When the nodes have become very large and form a massive chain from the level of the ear to that of the clavicle, the best results may require two or four fields on one or both sides (Fig. 3). In this event the neck is divided as evenly as possible by a line extending from the lobe of the ear, or higher, down to about the middle of the clavicle; the width of the fields depends on the size of the neck and extends

from this line to the median line anteriorly, and posteriorly to a line which follows the hairline downward and includes the anterior border of the trapezius muscle. The two or four beams of rays are directed so as

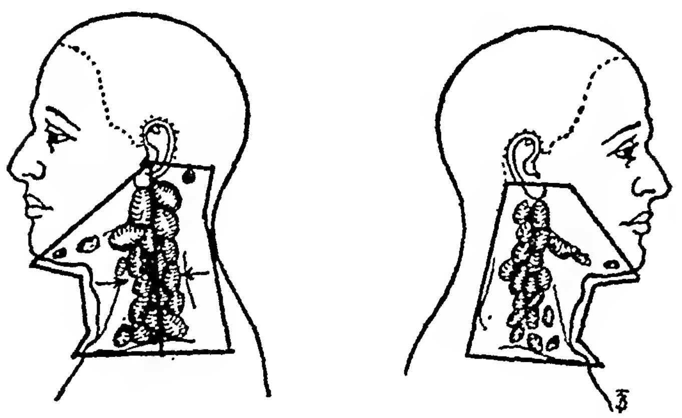

FIG. 2. The fields of roentgen treatment when the cervical nodes on the left side are numerous and rather large while the right cervical nodes are only moderately enlarged (two fields on left side and one field on the right side).

to converge on the enlarged nodes from either side of the central dividing line.

When, as not infrequently happens, the nasopharynx, pharynx or tonsils are primarily or secondarily involved, the treatment must take into consideration not only the affected structures on one or both sides but also the extent of involvement

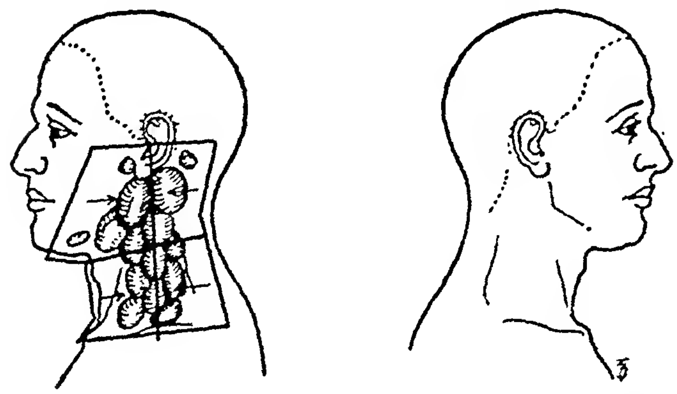

FIG. 3. Four fields of roentgen treatment on the left side of the face and neck when the left cervical nodes are greatly enlarged.

and the thickness of the neck and face. Effective treatment may be possible through a single field on one side, or it may be necessary to arrange the treatment through two lateral fields on one or on each side (Fig. 4). Sometimes the malignant process may have extended to one of the antrums or to the other accessory sinuses. In this event, one or two additional anterior fields may have to be provided. Of course, extensive involvement such as this usually occurs only when the pathologic process has reached a rather advanced stage. Substantial improvement may result even then, but the improvement is not likely to last as long as it does when the condition is less advanced.

Axillary Lymphadenopathy. In many cases, the axillary nodes are not perceptibly enlarged and do not require treatment. In other cases these nodes are slightly or moderately enlarged; in this

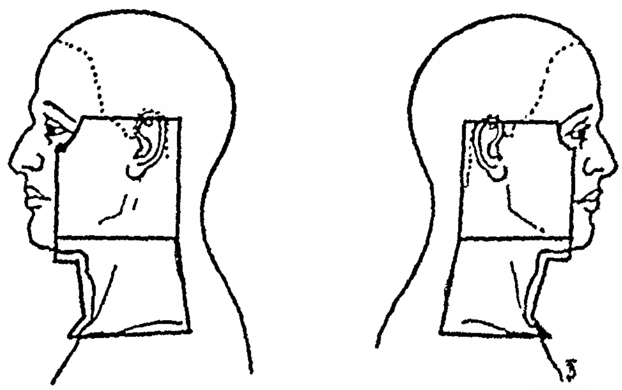

FIG. 4. The fields of roentgen treatment when Hodgkin's disease or lymphosarcoma has invaded the nasopharynx or tonsil. This is in addition to the lower fields through which treatment is given to the cervical nodes in the lower half of the neck.

event, satisfactory treatment can be given through an axillary field on one or both sides, the patient being placed, and the arm raised, in such a way that the rays can be directed into the axilla at an angle corresponding to the axis of the axillary space. Sometimes many nodes throughout the axillary space, from the clavicle to the armpit, may be affected; then, it is best to irradiate the entire axillary space on one or both sides through an axillary field and also through an anterior field which includes all the tissues from the clavicle to the armpit. In extreme cases, it may be advisable to add a third, posterior, field.

Mediastinal Lymphadenopathy. When treatment is directed toward the mediastinum and is arranged through a single

anterior, central field or through an anterior and a corresponding posterior field, it is usually followed by slight or moderate regression of the nodes and improvement in the respiratory and vascular symptoms, but the improvement seldom lasts long. Much greater and more lasting regression and improvement can be obtained by irradiating the affected intrathoracic structures through two large anterior and two corresponding posterior fields (Fig. 5), when these four fields are well placed, when the four beams of rays converge on the mediastinum, and when a sufficient dose of radiation is given within a reasonably short time. The upper

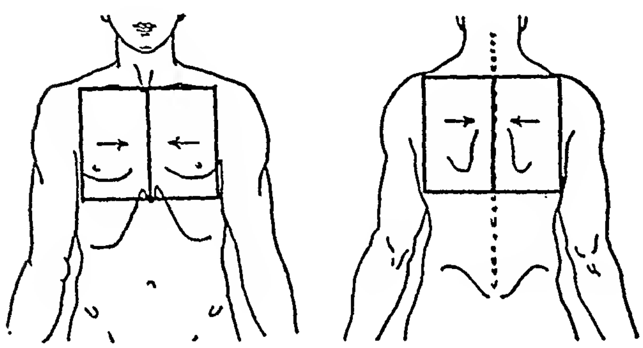

Fig. 5. Arrangement of the fields when roentgen treatment is directed toward the mediastinum and inner third of the lungs.

limits of the fields should correspond to the level of the suprasternal notch, and their lower limits should correspond to the level of the ensiform cartilage. Laterally, or transversely, the fields should extend from the median line to the anterior or posterior axillary line, as the case may be. The degree of convergence of the beams of rays varies according to whether involvement is confined to the mediastinal and hilar nodes or whether the malignant lymphoid process extends toward or to the chest wall.

Retro-abdominal Lymphadenopathy. When the pathologic process affects mainly the para-aortic nodes in the upper half of the abdomen, especially those in the region of the celiac axis, treatment should be directed toward this region through two large anterior fields and two corresponding posterior fields. These fields should extend longitudinally from the level of the ensiform cartilage to that of the navel, and transversely from the median line to the anterior or posterior axillary line (Fig. 6). When all the abdominal nodes (para-

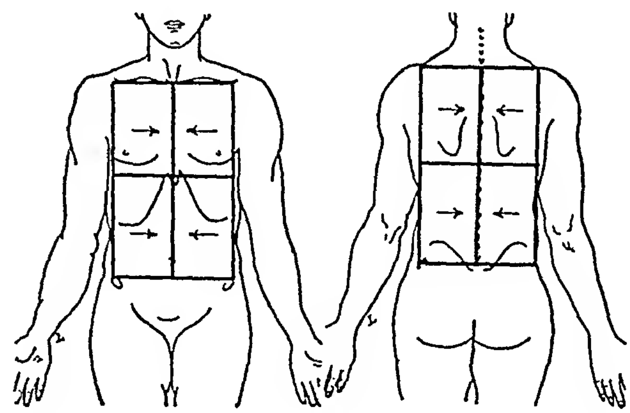

Fig. 6. Arrangement of the fields when roentgen treatment must be directed not only to the mediastinum but also to the upper two-thirds of the abdomen.

aortic, mesenteric and iliac nodes) are involved, the entire abdomen should be treated through four large anterior and either two or four posterior fields (Fig. 7), according to the circumstances in each case. When the inguinal nodes also are involved and require treatment, the line

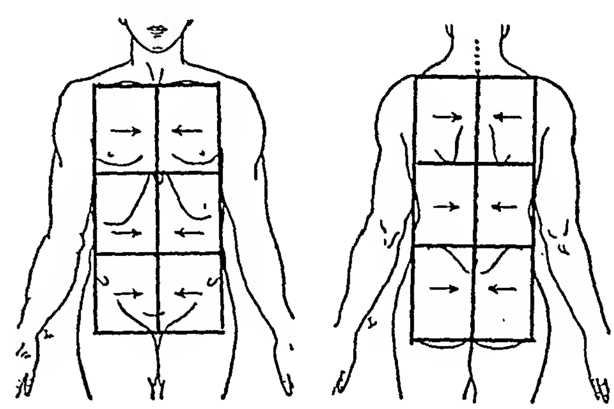

Fig. 7. Arrangement of the fields when roentgen treatment must be directed not only to the mediastinum but to the entire abdomen.

dividing the two upper abdominal fields from the two lower fields should pass a little below the navel, and the lower fields should extend downward so as to include all of Scarpa's triangle.

Quality of Roentgen Rays. Because the consensus now is that difference in wavelength per se does not influence the effect of the roentgen rays, it is generally assumed that all tumors, and even inflammatory lesions, may be treated with rays of the same quality, generated usually at or about 200 kv. Some radiologists even use rays generated at voltages between 400 kv. and 1,000 kv. Roentgen rays generated at 200 kv. or more have the advantage of delivering a greater dose at a depth of, say, 10 cm.; they induce less severe cutaneous reactions, and, at the higher voltages, they tend to induce less radiation sickness. These advantages may be of considerable importance in treating relatively resistant tumors, such as epithelial tumors of the uterus, bladder, prostate gland or rectum, but in treating Hodgkin's disease, these apparent advantages may lead one to overlook other factors which may be even more important.

The lymphoid cells, which are such important features of lymphoblastomatous tumors, are much more sensitive to roentgen rays than is generally realized. Therefore, effective treatment does not require the maximal dose of radiation in a given time that is required for tumors made up chiefly of epithelial cells. When the enlarged nodes are relatively superficial, as in the neck, armpits or groins, the level of absorption also becomes important. The greater the proportion of a beam of rays which penetrates the body to a depth of 10 cm., the smaller is the proportion of this beam absorbed by the first 3 cm., and vice versa. When treatment is directed against enlarged nodes in the neck, armpits or groins therefore, roentgen rays generated at a voltage of 130 or 140 kv. are more effective because a greater proportion of the rays are absorbed by the affected nodes. Even when the nodes are very large, rays generated at this voltage are often, although not always, more effective than those generated at 200 kv. or more. When, owing to massive enlargement of the nodes, it becomes important to produce the greatest effect in a short time, this can usually be done more effectively by increasing the number of fields, and therefore of beams of rays, than by increasing the voltage.

When the problem is to treat enlarged nodes in the mediastinum or abdomen, the tendency again is to employ roentgen rays generated at 200 kv. or more. In some cases especially when the patient is a person of unusual size or exceptionally obese, the more penetrating rays may produce the most favorable result, but in the average case rays generated at a medium voltage (130 or 140 kv.) will be found as effective, and often more effective, provided the number, size and position of the fields are carefully planned, and provided the beams of rays are well directed.

For many years, I have had ample opportunity to observe the different effect of roentgen rays generated at 200 kv. or more and of those generated at a potential between 130 and 140 kv. Moreover, clinical tests of treatment carried out at the two ranges of voltage convinced me of the superior effect of rays of moderate wavelength, and extended observation of patients treated by other radiologists with rays of shorter wavelength has only served to strengthen this conviction. In all probability the difference is not due to the difference in wavelength per se, but it is due partly to a difference in the quantity of rays absorbed, partly to the great sensitiveness of lymphoid cells, and perhaps also to other factors which are still obscure. It seems likely that these "obscure factors" consist mainly in a difference in the quantity of rays. When treatment is given with roentgen rays generated at 200 kv., the affected lymph nodes usually do not retrogress so much and, especially when the same region is treated repeatedly, diffuse induration tends to develop and the lymph nodes rapidly become resistant to further treatment. For these reasons, the treatment must be given up after a relatively short time; this is especially true when each field is exposed to an excessive

quantity of rays. When, on the contrary, treatment is given with roentgen rays generated at moderate voltage (130 to 140 kv.), diffuse induration of the tissues in the exposed fields is less likely to occur and the affected nodes continue to respond to treatment for a longer time. This applies to lymph nodes in the abdomen and mediastinum as much as to those in the neck, armpits, and groins. When an excessive quantitative dose of roentgen rays generated at moderate voltage is given to any field, especially when this is repeated a number of times, induration of the skin and subcutaneous tissue is likely to develop, but usually this develops more slowly. When excessive doses are avoided, diffuse induration does not develop and the affected nodes continue to respond for a long time. It is apparent, therefore, that the quantity of roentgen rays (surface or skin dose) is an important element.

As Duane pointed out many years ago, when roentgen rays generated at moderate voltage (130 to 140 kv.) are employed, aluminum is a more efficient filter than copper. When the cervical nodes are moderately enlarged, 4 mm. of aluminum is used as a filter. When nodular infiltrations of the scalp or skin must be treated, 4 mm. of aluminum provides adequate filtration. When the cervical nodes are large and numerous, an aluminum filter 6 mm. thick is preferable. When treatment is directed toward the mediastinal or retro-abdominal nodes, 6 mm. of aluminum should be used.

Exceptionally, such as when the nasal accessory sinuses, the nasopharynx or the tonsil are involved, roentgen rays generated at 200 kv. or more and filtered through 0.75 mm. of copper and 1.0 mm. of aluminum yield superior results.

Quantity of Roentgen Rays. Because in epithelial and other tumors effective destruction of the malignant cells requires the largest dose of roentgen radiation which can be given with safety, it is widely assumed that the same is true of all malignant processes. When lymphoblastoma is limited to a single region, and especially when it is confined to a small cluster of nodes, the hope of effecting a permanent cure may reasonably be entertained, and a complete result can sometimes be achieved. Even then, however, doses of the order of those required for epithelioma are not necessary. The lymphoid cells in the affected lymph nodes are usually so sensitive to the radiation that much smaller total doses are sufficient.

Occasionally, when the pathologic process appears to be confined to a single group of nodes, the attempt to effect a permanent cure by concentrating the maximal dose of radiation on the affected nodes may be justified. In the great majority of cases, when the patient consults a physician, the malignant lymphoid process has already invaded two or more groups of nodes in different regions. Not infrequently, the process has already reached an advanced stage in its course, and sometimes it is already near or actually in the terminal phase. Under these circumstances, a cure is impossible, and the most that can be expected is a variable degree of improvement for a variable period of time. When lymphoblastoma is not too advanced, and especially when it has a relatively chronic form, the patient's condition is susceptible of great improvement, and he may survive from five to twenty years, or even longer. In all these cases the aim of the radiologist should be to maintain this improvement as long as possible. This can seldom be achieved by the method of maximal total doses made possible by protracted fractional irradiation. To follow this course may yield excellent initial results and treatment may be repeated once or twice at the most. But when the pathologic process again becomes active, further treatment is impossible or, if it is undertaken, it has little if any effect and the patient no longer obtains relief.

A more effective method, in my estimation, is to give to each field, in one or two days, as large a dose of radiation as can be given without taxing the tolerance of the

skin and other tissues or of the patient as a whole. As a rule, such a dose is between 550 and 600 roentgens (surface dose, measured in air). The different fields are thus treated successively, one at a time, until all the fields have received the specified dose. The number of days required to complete the course of treatment depends on the extent of involvement and the number of fields to be irradiated, as well as on the tolerance of the patient. When a single cervical field requires treatment, this may be given in one or two days, but when most of the lymph nodes must be treated, from ten to sixteen days may be required. Many patients cannot tolerate 550 roentgens (one field) a day; this is especially true when treatment is directed toward the upper half of the abdomen. In this event it is advisable to give only 275 roentgens (half of one field dose) on successive days, treatment of each field being completed before another field is treated. Most patients can tolerate 275 roentgens a day without undue difficulty, but occasionally a patient can tolerate only 175 or 200 roentgens a day.

Time Distribution of Treatment. From time to time I have seen patients who have told me that they had previously been treated with roentgen rays for one month or for several months. When asked whether the treatment had caused the enlarged lymph nodes to recede and their condition to improve, they have replied that at first the nodes diminished slightly for a short time, but later the treatment remained without perceptible effect. Upon inquiring into the chronologic arrangement of the treatment, I was told that treatment had been given only once or twice a week. Yet, when these patients were treated according to the general scheme which I have described, the nodes regressed, and the general condition improved as rapidly and as much as if they had never been treated at all. Later, when the pathologic process again became active, additional treatment has again, and repeatedly, produced satisfactory improvement. There seems to be no doubt that the reason the previous treatment had yielded only slight and transient benefit in these patients was largely that the interval between sessions had been too long or that the quantity of roentgen rays given at each session had been too small. My own conclusion is that frequently both factors are responsible. Treatment once a week or even twice a week cannot possibly produce the improvement to which the patient is entitled.

Sometimes, the slight initial improvement and subsequent failure to improve are attributed to an increased resistance of the affected lymph nodes, but when these same nodes and these same patients improve satisfactorily under a different scheme of treatment, the assumption of increased resistance obviously does not rest on a sound basis. This problem of increasing resistance of cells has interested me for many years. As far as the lymphoid cells are concerned, the principal factor in increasing resistance to irradiation appears to be excessive quantitative doses. If these are avoided, and if clinical factors in each case do not account for increased resistance, the affected nodes and structures continue to respond for a long time. It is true that as time goes on, especially in the chronic form of lymphoblastoma, some increase in resistance gradually develops, but this is slow. In my experience, the main causes for failure of lymphoblastomatous lesions to respond are: (1) an advanced stage or terminal phase of the pathologic process; (2) excessive quantitative doses of roentgen radiation within a given time.

When the patient is first seen, two courses of roentgen treatment, with an interval of three weeks between them, may be sufficient to bring the pathologic process under control for a time. A single course of treatment may be followed by more or less marked improvement and this may continue for a certain length of time, but, when a second course is given three weeks later, the improvement is much greater and lasts longer. In other cases, especially

when lymph nodes in two or more regions are greatly affected, it is often advisable to give a third course of treatment three to six weeks after the second course. Then, the patient should not receive any more treatment for as long a time as possible, but he should be examined every three or six months. How often subsequent roentgen treatment may have to be given varies greatly in different cases. Some patients require additional treatment every few months, while others require treatment at longer intervals; some have to be treated only at intervals of two or three years, and some go even longer.

Pathologic Factors Which Influence the Effect of Roentgen Treatment. Occasionally a patient is encountered in whom the lymphoblastomatous tumors do not retrogress at the rate or to the degree expected. Frequently, this is because the pathologic process has reached an advanced stage or has entered the terminal phase. When failure of the enlarged nodes to retrogress as usual is not due to this factor, it can almost always be traced to one of the following causes: (1) the presence in the mass or masses of enlarged nodes of an exceptional proportion of connective tissue; (2) the presence of old calcified deposits in some of the nodes; (3) the presence of secondary infection. The first two factors seem to occur chiefly in mediastinal tumors, whereas the third factor seems to occur chiefly in the cervical nodes. All three, however, are uncommon.

Clinical Factors Which Influence the Effect of Roentgen Treatment. Besides the extent of involvement, two other factors have an important bearing on the results which may be expected from roentgen treatment. One is the relative acuteness or chronicity of the malignant process in each case. In some cases lymphoblastoma runs a comparatively short course, and the time which elapses between the apparent onset of the disease and the death of the patient may vary between six months and two or three years. In other cases the course of the process may extend from three to five or six years; these constitute the intermediate group. In still other cases the condition may persist from five to twenty years, or longer. In cases of relatively acute lymphoblastoma, roentgen treatment may be followed by exceptionally rapid regression, but this is of short duration. In the chronic cases, proper roentgen treatment is often followed by marked regression and prolonged improvement. These are the cases in which long remissions are obtained.

The other clinical factor is the stage of the malignant process. Sooner or later, in practically every case, the condition reaches an advanced stage in its evolution and finally enters the terminal phase. When this occurs, the enlarged lymph nodes or other diseased structures respond to roentgen treatment less and less. Usually, this failure of response is associated with other signs of advanced disease, but perhaps the best single indicator is the numerical status of the red blood corpuscles. As long as they remain at or near the normal level, the patient may be expected to derive improvement from roentgen treatment; but when their number begins to diminish more or less steadily, this is usually the beginning of the end. Death may not occur for six months or may be delayed for three years, but a more or less steady decrease in the number of erythrocytes usually means that the end is approaching.

REFERENCES

1. Desjardins, A. U. Radiosensitiveness of cells and tissues, and some medical implications. *Arch. Surg.*, 1932, *25*, 926–942.
2. Desjardins, A. U. A classification of tumors from the standpoint of radiosensitiveness. Am. J. Roentgenol. & Rad. Therapy, 1934, *32*, 493–499.
3. Desjardins, A. U. Retroperitoneal lymph nodes; their importance in cases of malignant tumors. *Arch. Surg.*, 1939, *38*, 714–754.
4. Despeignes, V. Observation concernant un cas de cancer de l'estomac traité par les rayons Röntgen. *Lyon méd.*, 1896, *82*, 428–430; 503–506.
5. Duane, W. Roentgen rays of short wave-lengths and their measurement. Am. J. Roentgenol., 1922, *9*, 167–171.

6. Heineke, H. Ueber die Einwirkung der Röntgenstrahlen auf Tiere. *München. med. Wchnschr.*, 1903, *50*, 2090–2092.
7. Heineke, H. Zur Kenntnis der Wirkung der Radiumstrahlen auf tierische Gewebe. *München. med. Wchnschr.*, 1904, *51*, 1382–1384.
8. Heineke, H. Experimentelle Untersuchungen über die Einwirkung der Röntgenstrahlen auf innere Organe. *Mitt. a. d. Grenzgeb. d. Med. u. Chir.*, 1905, *14*, 21–94.
9. Nogier, T., and Regaud, C. Action des rayons X sur le testicule du chien. Conditions de la stérilisation complète et définitive. *Compt. rend. Soc. de biol.*, 1911, *70*, 50–52.
10. Regaud, C. Action des rayons de Röntgen sur l'épithélium séminal. Application des résultats à certains problèmes concernant la structure et les fonctions de cet épithélium. *Compt. rend. de l'Assoc. d. anat.*, 1907, 9, 30.
11. Regaud, C. Sur les variations de la radiosensibilité (aux rayons X) des cellules nourricières de l'épithélium séminal, chez le rat. *Compt. rend. Soc. de biol.*, 1913, *74*, 1256–1259.
12. Regaud, C. Influence de la durée d'irradiation sur les effets déterminés dans le testicule par le radium. *Compt. rend. Soc. de biol.*, 1922, *86*, 787–790.
13. Regaud, C. Le rythme alternant de la multiplication cellulaire et la radiosensibilité du testicule. *Compt. rend. Soc. de biol.*, 1922, *86*, 822–824.
14. Regaud, C., and Blanc, J. Action des rayons X sur les diverses générations de la lignée spermatique. Extrême sensibilité des spermatogonies a ces rayons. *Compt. rend. Soc. de biol.*, 1906, *61*, 163–165.
15. Regaud, C., and Blanc, J. Action tératogène des rayons X sur les cellules séminales. *Compt. rend. Soc. de biol.*, 1906, *61*, 390–392.
16. Regaud, C., and Blanc, J. Action des rayons de Röntgen sur les éléments de l'épithélium séminal. *Compt. rend. Soc. de biol.*, 1906, *61*, 652–654.
17. Regaud, C., and Dubreuil, G. Action des rayons de Röntgen sur le testicule du Lapin. I. Conservation de la puissance virile et stérilisation. *Compt. rend. Soc. de biol.*, 1907, *63*, 647–649.
18. Regaud, C., and Nogier, T. Stérilisation complète et définitive des testicules du rat, sans aucune lésion de la peau, par une application unique de rayons X filtrés. *Compt. rend. Acad. d. sc.*, 1909, *149*, 1398–1401.
19. Regaud, C., and Nogier, T. Sur la stérilisation du testicule du chat par les rayons X. Conditions techniques de sa réalisation. *Compt. rend. Soc. de biol.*, 1911, *70*, 5–7.
20. Regaud, C., and Nogier, T. Stérilisation röntgénienne, totale et définitive, sans radiodermite, des testicules du Bélier adulte. Conditions de sa réalisation. *Compt. rend. Soc. de biol.*, 1911, *70*, 202–203.
21. Regaud, C., and Nogier, T. Sur l'hypertrophie compensatrice de la glande interstitielle du testicule consécutive à la castration unilatérale chez des animaux préalablement stérilisés par les rayons X. *Compt. rend. de l'Assoc. d. anat.*, 1911, *13*, 293.
22. Symmers, D. Clinical significance of the deeper anatomic changes in lymphoid diseases. *Arch. Int. Med.*, 1944, *74*, 163–171.
23. Warthin, A. S. An experimental study of the effects of roentgen rays upon the blood-forming organs, with special reference to the treatment of leukemia. *Internat. Clin.*, 1906, s. 15, *4*, 243–277.
24. Wood, F. C., and Prime, F., Jr. The action of radium on transplanted tumors of animals. *Ann. Surg.*, 1915, *62*, 751–765.

Vol. 54, No. 6

BIOLOGICAL EVALUATION OF 20 MILLION VOLT ROENTGEN RAYS*

I. ACUTE ROENTGEN DEATH IN MICE

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INTRODUCTION

THE betatron, which was invented at Illinois by Kerst,[3,4,5] is an instrument which produces roentgen rays of very high quantum energy. It is similar to conventional roentgen apparatus in that the radiation is the result of the collision of a stream of electrons with a metallic target. The fundamental difference lies in the mode of acceleration of the electrons. The conventional types of roentgen equipment involve the application of large voltages between electrodes, the electrons being accelerated by this potential difference. The betatron uses magnetic induction. The stream of electrons is curved into a circle by the action of a magnetic field and accelerated by increasing the strength of the field. After reaching a predetermined energy the electrons are made to strike a target, yielding a burst of roentgen radiation. In order to repeat the process, the magnetic field is reduced to zero. The cycle is repeated 180 times a second, producing as many bursts of radiation. In our experiments, the roentgen rays had a peak energy of 20 million volts.

The secondary electrons from high energy roentgen rays travel almost entirely in the direction of the primary beam and are much more penetrating than those from conventional roentgen rays. The range of a 20 megavolt electron is about 10 centimeters in water, as compared to ranges of about 3.5 cm. for 10 megavolts, about 1 cm for 1 megavolt, and about 1 millimeter for 200 kv. Thus, where high energy roentgen rays strike an object, the density of ionization, i.e., the depth dose, will increase to a maximum below the surface, and only from there on will it slowly decrease. Preliminary measurements[6] indicate that, for 20 million volt roentgen rays, at a target distance of 45 cm., the maximum depth dose occurs at a level of about 3 cm., and amounts to about three times the surface dose. Beyond the maximum, the depth dose falls slowly. At 10 cm., it is about 75 per cent of the peak dose, or 225 per cent of the surface dose. It follows that, if we were to irradiate a focus in the depth of the body with 20 million volt roentgen rays, the entry portal would receive a comparatively small dose while the exit portal would receive about 50 to 80 per cent of the tumor dose.

A beam of rays with a depth dose distribution as described must have a different effect from that caused by conventional rays if the irradiated object, as a whole, is large enough to register the peculiar depth dose distribution. Since the human body is large enough to permit the operation of this factor, it is to be expected that the betatron radiation will add new resources to the treatment of deep-seated cancer.

However, significant as the depth dose distribution is, it may not be the only difference of therapeutic importance. The effects of the high energy radiation may also vary in other equally important aspects which concern reactions occurring in any volume element, independent from the dosage distribution in the whole body. The effect on living tissue, in general, may be different in quality: there may be specific reactions completely foreign to those accompanying the use of the conventional roentgen ray. It must be remembered that qualitatively different absorption processes occur at the energy levels of the rays produced by the betatron. The effects on living tissue may be different in quantity: there may be a difference in doses required, a difference which may be a constant one, easily

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compensated by the use of a correction factor, or which may be found to vary differently for each particular tissue and reaction. Obviously, only biological experiment can answer these questions. The object, therefore, of this series of investigations is to compare the effects of a betatron

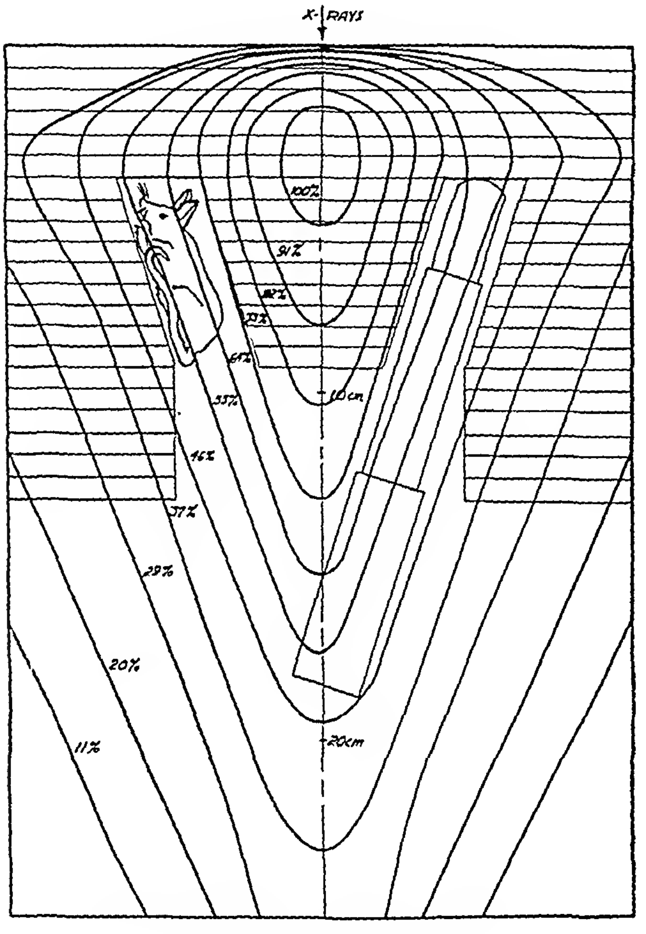

Fig. 1. Isodose lines superimposed on the mouse phantom.

and a conventional deep therapy machine under experimental conditions where the differences in depth dose distribution are eliminated, thus isolating for study all other possible differences of action.

MATERIAL AND METHODS

As the first biological test object, we selected mice and submitted them to lethal doses administered homogeneously to the whole body. Mice have been used in biological dosimetry as early as 1912.[8] In recent times, Lawrence and Tennant[7] have used mice for the bio-assay of fast neutrons, and Ellinger[2] for the demonstration of backscattering. We considered mice a favorable object because their reactions could be checked in great detail with the vast information assembled on irradiation reactions in mammals; also, mice are small enough to allow nearly homogeneous irradiation, thus excluding any dosage distribution factors.*

The influence of the peculiar depth dose distribution was eliminated by irradiating the mice in a phantom designed to obtain approximately homogeneous dosage throughout the body of the animals. To determine the shape of the isodose surfaces in the phantom, a film, with 4 inches of presswood (density, 1.1) on each side, was exposed with the central beam passing along the center of the film.[5] The film was examined photometrically. Lines of constant density were regarded as isodose lines. The relative intensities were determined from the density characteristics of the film. With 20 million volt radiation, and a target distance of 70 cm. to the top of the phantom, the isodose lines are the curved lines in Figure 1.

The phantom was constructed of nine sheets of 16 by 16 by $\frac{1}{4}$ inch pressdwood which were bolted together, with six 1 inch holes drilled along isodose surfaces, as shown in Figure 1. Six sheets of the same material were added in front of the phantom, and six on each side in back in order to allow for backscattering.

The phantom was calibrated by inserting several Victoreen thimbles in various holes and observing the ratios of readings for a given exposure. In operation, a 250 r thimble was placed in one of the holes, and read approximately every 200 r, so that a measure of the dose given to each mouse was obtained. This dose was correct within ±10 per cent, as established from the dose distribution curve and direct dosimeter readings.

After the irradiation, the mice were observed mainly in order to determine the survival time, i.e., the time elapsing between irradiation and death. In addition, the weight

* The animals used in these experiments were C57-Black mice. They were given to us by Dr. Herman B. Chase, of the Department of Zoology, University of Illinois. The mice were kept in wooden bins, on a diet of "Purina" dog chow and water.[1]

was taken daily, and general impressions recorded. After death, an autopsy was performed, and several organs preserved for pathological examination.

RESULTS

Mice subjected to total body irradiation with 20 million volt roentgen rays react, qualitatively, the same way as mice treated with 200 kilovolt rays. They lose weight, show anorexia and diarrhea, become anemic, their fur gets flurry, and they recover or die under progressive cachexia, depending on the size of the dose. Pathological examination reveals severe damage in many vital organs.[9,10] Within the range of our observations, we found in betatron mice all the reactions known to occur in mice treated with comparable doses of conventional roentgen rays, and no new, previously unknown effect.

The difference between the two radiations appears when the quantitative dose-response relations are considered. To obtain comparable reactions, higher doses are needed of the 20 million volt rays than of the 200 kilovolt rays, the doses being expressed in both cases in roentgens measured with the Victoreen thimble in a phantom, and the r per minute rates being of the same order.

The difference in effectiveness was established, quantitatively, by evaluating the relations between survival time and dosage. It has been found[9,10] that the survival time is inversely proportional to the square of the dose, for a dosage range from 650 to 1,175 r applied to mice weighing 20 gm. For mice of varying weight, subjected to constant doses, the survival time is directly proportional to the weight. Combining both observations one obtains the formula:

$$T.D^2/W = 2.3 \times 10^5$$

$$(2.1 \times 10^4 < D^2/W < 6.9^9 \times 10^4 \text{ r}^2\text{gm}^{-1}) \qquad (1)$$

where T is the expected survival time, D the dose in r, and W the weight in gm. at the time of irradiation. The formula is valid only for a certain range of D^2/W viz., from 2.1 to 6.9×10^4 r^{2}gm^{-1}, always referring to our standard strain, C57-Black. Below and above this range, survival times remain constant despite considerable changes of dosage. Near the points of inflexion of the curve, the dose-response relations are ill defined. Thus, the range favorable for bio-assay is between values of dose^2/weight from 2.2 to 5.6×10^4 r^{2}gm^{-1}, or for an equivalent dosage range of another radiations.

The survival times in 35 mice killed by 20 million volt roentgen rays are assembled in Figure 2. The ordinate represents survival times, the abscissa the quotients "dose^2/weight" and, on a second scale, the corresponding doses for a mouse weighing 20 gm. The scales are logarithmic. Every symbol stands for an individual observation. The dashed line is the dose-response curve established for conventional 200 kv. roentgen rays.[9,10] The results obtained with the betatron can be adequately represented by a broken line parallel to the one found with 200 kv. rays, differing only in its relation to the dosage axis. The distance between the two curves yields the factor of equivalence between 20 million volt rays and 200 kv. rays. From Figure 2, the distance between the two curves equals 0.38 (logarithmic difference). Thus:

$$\log \text{Dose}^2 \text{ (betatron)} - \log \text{Dose}^2 \text{ (200 kv.)} = 0.38 \qquad (2)$$

$$\text{Dose (betatron)} \times 0.65 = \text{Dose (200 kv.)}$$

i.e., 1 r of the betatron radiation is equivalent to 0.65* r of 200 kv. radiation, both radiations measured with the Victoreen thimble in a saturated beam, the effectiveness being defined with respect to the survival time of mice.

The reliability of the value 0.65 can be derived from a consideration of the deviations of actual survival times from the expected values, $T = \text{const.} \times D^2/W$ (see ref. 9 and 10). A statistical computation shows that the true value of the conversion factor lies in the range from 0.54 to 0.75 (with a probability of 95 per cent). A more accurate determination would neces-

* Some additional data have been obtained since this paper was written. From the total material at hand, at the present time, the best estimate of the conversion factor is 0.78.

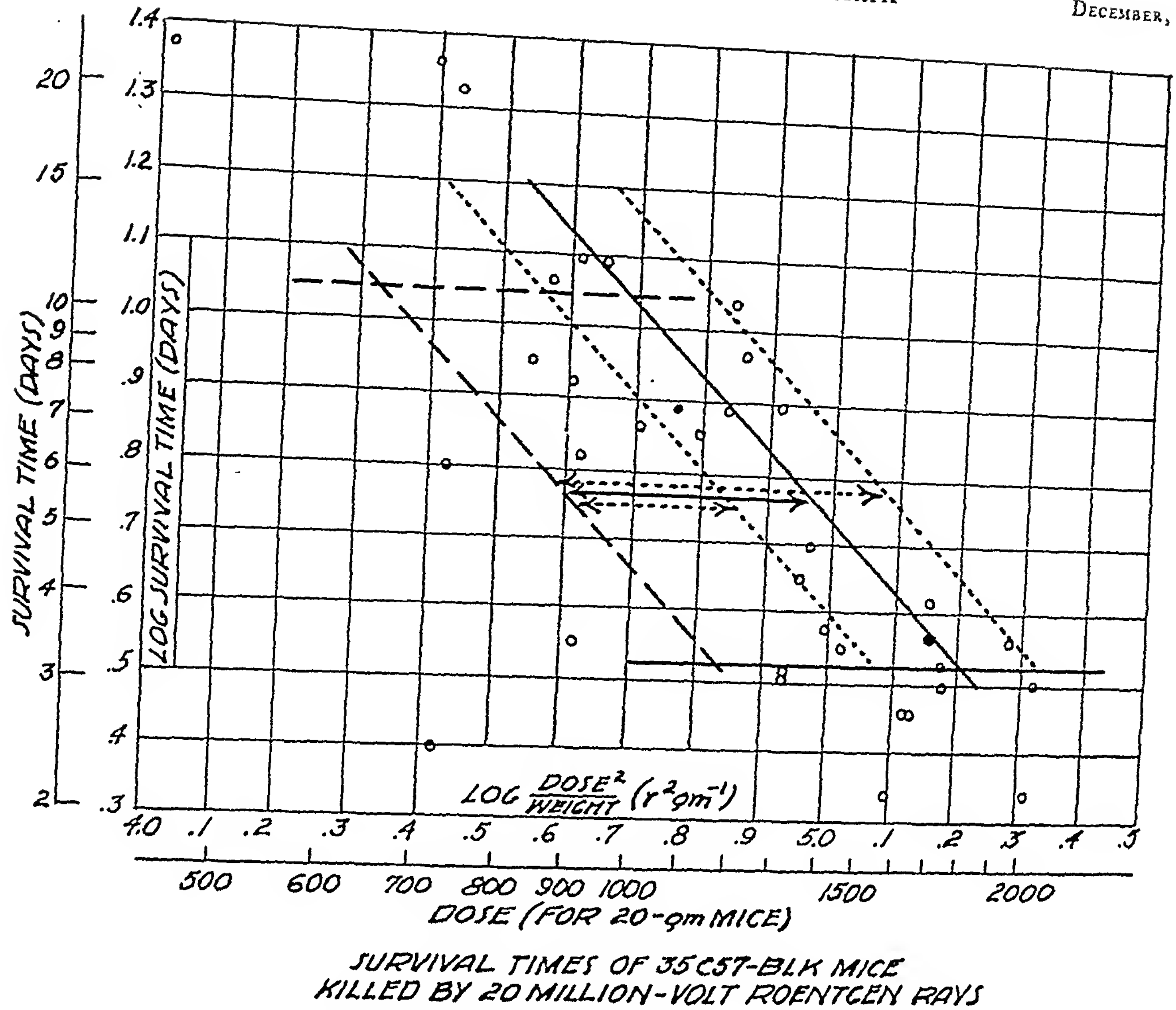

Fig. 2. Survival times of thirty-five C57-Black mice killed by 20 million volt roentgen rays. Ordinate—survival time; abscissa—dose²/weight, and corresponding doses for 20 gm. mice; symbols—individual observations; dashed line—dose-response curve for 200 kv. rays; heavy line—trend of the betatron results; heavy arrow—conversion factor; dotted lines and arrows—statistical margins of the estimates.

sitate much more experimentation, and was not considered useful at the present time.

The way the data were evaluated is based on the assumption that the survival time-dose relation has the same characteristics for both betatron and conventional rays. This assumption, in turn, rests on the fact that we have not found anything suggesting a qualitative difference in the actions of both kinds of radiation; the experimental data submit readily to this way of curve fitting. However, it is admitted that the betatron data as they stand do not suggest strongly the type of curve chosen. One might fit a straight line, instead of a Z-shaped broken line, to the experimental points. This procedure leads to factors ranging from 0.68 to 0.88. Generally speaking, all functions that can be reasonably used to represent the experimental data, lead to factors which are of the same order as our value of 0.65*, with differences too small to be significant at the present stage of investigation.

DISCUSSION

We regard the absence of specific betatron effects as the most significant result of these experiments. If further investigation confirms the belief that high and low energy roentgen rays act on biological objects qualitatively in the same way, it will be permissible to adapt to the betatron knowledge acquired with ordinary rays. Thus therapy will be possible soon, giving us the full advantage of the peculiar depth dose distribution.

The quantitative difference in effective-

* See footnote page 725.

ness thus far apparent cannot be disregarded. It is not large, nor is it negligible. It must be emphasized that the difference was found under specified conditions, using as a physical measure the discharge of the Victoreen r-meter, and as a biological measure the survival time of mice. Either of these measures may deviate from the absolute standard. The Victoreen thimble is an absolute dose indicator at ordinary energies, but it is not known how it reacts to 20 million volt roentgen rays. The biological measure may deviate from the absolute standard because of the qualitative differences in physical absorption processes. Furthermore, the spacing of the ion pair production is not the same for the two kinds of radiation, nor is the timing, the betatron rays coming in short intense bursts. However, no theory, based on our present knowledge, can be convincing. We must have additional experimental evidence, some of which we hope to procure in investigations now in progress.

SUMMARY

1. It can be predicted, on the basis of established depth dose curves, that the high energy radiation of the betatron will be useful in the treatment of deep-seated cancer.

2. It cannot be predicted how the betatron radiation will act on any element of living tissue.

3. The elementary actions of high energy roentgen rays must be established by biological evaluation, conducted in such a manner that the influence of the depth dose distribution is eliminated.

4. Mice were subjected to irradiation of the whole body with a homogeneous dose of 20 million volt roentgen rays.

5. Qualitatively, the clinical and pathological effects observed were the same as those attending the use of conventional roentgen rays.

6. A quantitative evaluation of effectiveness was obtained, using the Victoreen r-meter as a physical measure and the survival time of mice (between irradiation and death) as a biological measure. It was found that, under the conditions stated, 1 r of the 20 million volt rays of the betatron is equivalent to about 0.65*r of the conventional 200 kilovolt rays.

7. The significance of this conversion factor will be established only by further experimental investigation.

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We wish to express our gratitude to Professors D. W. Kerst and G. M. Almy, of the Department of Physics, and to Dr. Herman B. Chase, of the Department of Zoology, for their kind interest and generous help at various phases of this investigation.

REFERENCES

1. CHASE, H. B. Studies on an anophthalmic strain of mice. III. Results of crosses with other strains. *Genetics*, 1942, *27*, 339–348.
2. ELLINGER, F. Lethal dose studies with x-rays. *Radiology*, Feb., 1945, *44*, 125–142.
3. KERST, D. W. Acceleration of electrons by magnetic induction. *Phys. Rev.*, 1941, *60*, 47–53.
4. KERST, D. W., and SERBER, R. Electronic orbits in induction accelerator. *Phys. Rev.*, 1941, *60*, 53–58.
5. KERST, D. W. The betratron. *Radiology*, 1943, *40*, 115–119.
6. KOCH, H. W., KERST, D. W., and MORRISON, P. Experimental depth dose for 5, 10, 15 and 20-million-volt x-rays. *Radiology*, 1943, *40*, 120–127.
7. LAWRENCE, J. H., and TENNANT, R. Comparative effects of neutrons and x-rays on the whole body. *J. Exper. Med.*, 1937, *66*, 667–688.
8. MEYER, H., and RITTER, H. Experimentelle Studien zur Feststellung eines biologischen Normalmasses für die Röntgenstrahlenwirkung. *Strahlentherapie*, 1912, *1*, 183–188.
9. QUASTLER, H. Studies on roentgen death in mice. I. Survival time and dosage. AM. J. ROENTGENOL. & RAD. THERAPY, Nov., 1945, *54*, 449–456.
10. QUASTLER, H. Studies on roentgen death in mice. II. Body weight and sensitivity. AM. J. ROENTGENOL. & RAD. THERAPY, Nov., 1945, *54*, 457–461.

* See footnote page 725.

HOOKWORM DISEASE

A SMALL INTESTINAL STUDY*

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and
CAPTAIN GEORGE P. KEEFER
Medical Corps, Army of the United States

FEW places in the world have a higher incidence of hookworm disease than the Province of Assam in India, where, according to Chandler,[1] 94 per cent of the individuals are infected. It was here that we gained our experience. Serving with a General Hospital in this area for over two years, we had ample opportunity to study hookworm disease as it developed in our American troops.

The purposes of this communication are to call attention to the fact that hookworm disease may produce changes in the small intestine early, and to describe the roentgen appearance of these changes. Whereas the statistical data presented were gleaned from the records of 74 patients, more than 125 were examined by roentgen methods. All had positive stools, but the hookworm species was identified in only 14 cases. Of these 8 were *Ankylostoma duodenale*, 2 were *Necator americanus*, and 4 were a combination of both.

In 1925, Henderson[3] described antiperistalsis in the duodenum which he considered a presumptive sign of intestinal parasitosis. More recently Yenikomshian and Shehadi[7] called attention to the fact that ankylostomiasis produced the clinical manifestations of duodenal ulcer which cleared after treatment by vermifuges. They observed alterations in duodenal peristalsis and mucosal pattern which they considered significant. The largest series of patients studied by roentgen methods was described in 1943 by Krause and Crilly.[5] They reported 97 young adults infested by *Necatur americanus*, all but 2 of whom were born and raised in southern United States. These authors concluded that the small intestinal pattern in ankylostomiasis simulated that described in the literature as the "deficiency pattern."

PATHOLOGY

In man, hookworm disease is usually due to *Ankylostoma duodenale* or *Necator americanus*. Whereas both are widely distributed throughout tropical and subtropical regions, *Ankylostoma duodenale* is more common in the Old World and *Necator americanus* in the New. The latter, however, is found frequently in India.

The life cycle of both species is about the same. When the eggs leave the bowel, they segment and form rhabditiform larvae which grow and moult, becoming small filariform larvae infectious to man. Under proper conditions these larvae become active and burrow rapidly through the skin of the exposed individual. They enter the veins and lymphatics which carry them to the heart and the lungs. Here the larvae penetrate the capillary and alveolar walls invading the air sacs, and eventually proceed up the bronchi and trachea to the epiglottis where they spill into the esophagus and are swallowed.[6]

Having reached the small intestine the larvae grow rapidly, becoming mature in about one month after entering the body. Here they develop mouth capsules and attach themselves to the intestinal mucosa from which they draw nourishment. Adult hookworms measure 10–12 mm. in length and 4–6 mm. in width (Fig. 1). They usually inhabit the distal duodenum, the jejunum, and the proximal ileum where mating occurs and new eggs are laid.

At autopsy the parasites are found at-

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tached to the intestinal mucosa or lying free in the lumen of the gut. Small punctate hemorrhages mark the areas in which their mouths are embedded and through which they suck blood.

Lieutenant Colonel J. S. Forrester found active hookworm infestation at autopsy in a patient who died in our hospital of scrub typhus. It is noteworthy that the patient was a native of Massachusetts and had been in Burma but two months before he died. His past intestinal history was uneventful. The autopsy was done about two hours after his death. The following report was submitted to us by Lt. Col. Forrester.

The stomach and esophagus are essentially normal. The jejunal wall seems a little heavy and boggy but this is not marked. The external surface of the small gut reveals some areas of patchy capillary congestion. The colon is negative.

On opening the gut a moderate number of *Ankylostoma duodenale* are found still attached to the mucosa. The concentration of worms is greatest in the mid-jejunum where 2–4 worms are seen in each 2–3 inch segment. There are no worms attached to the mucous membrane beyond a point 12 feet proximal to the ileocecal junction. The contents of the bowel were washed and sedimented. A total of 260 adult *Ankylostoma* were found in the sediment; all but 5 came from the jejunum and upper ileum (Fig. 1).

No gross lesions are noticed where the worms are attached to the mucous membrane although there are petechiae in nearby areas. The mucosa of the gut seems almost normal. There are no ulcerations or hypertrophied Peyer's patches.

Microscopically a portion of a hookworm is seen near its point of attachment to the jejunal wall. The worm contains some leukocytes and red blood cells. The jejunal villi are slightly edematous, a finding also noted in the submucosa. Plasma cells, lymphocytes and an occasional polymorphonuclear leukocyte are distributed sparsely throughout the entire thickness of the wall of the jejunum (Fig. 2).

The mucosal changes may be more advanced than those described above. The punctate hemorrhages may break down forming small erosions or frank ulcerations which become secondarily infected and penetrate the submucosa.

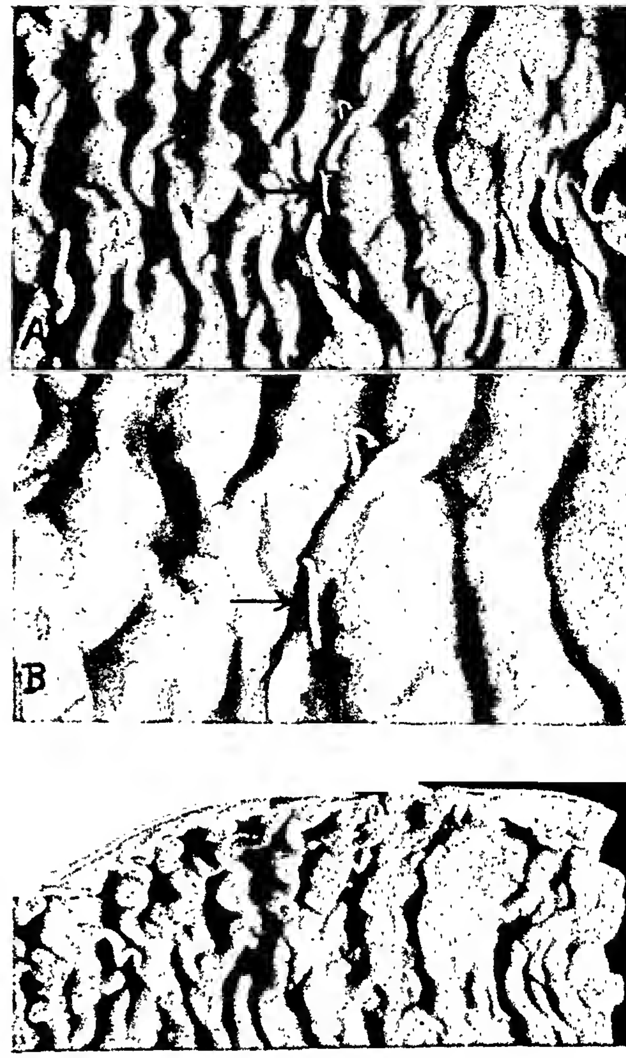

Fig. 1. Hookworm disease. Photographs of jejunum showing appearance of mucosal folds and hookworms. *A* reveals the normal or slightly accentuated appearance of the valvulae conniventes and several hookworms *in situ*. Close-up enlargement of hookworms seen in *B*. These were firmly embedded in the mucosa. Note the normal thickness of the wall of the intestine illustrated in *C*.

CLINICAL OBSERVATIONS

Krause and Crilly[5] divided their patients with ankylostomiasis into two groups: (1) those with significant symptoms whom they considered as having "hookworm disease," and (2) those in whom ova were an incidental finding which they called "hookworm infestation." Of the patients reported by Krause and Crilly 45 per cent had "hookworm disease" and 55 per cent, "hookworm infestation." Approximately

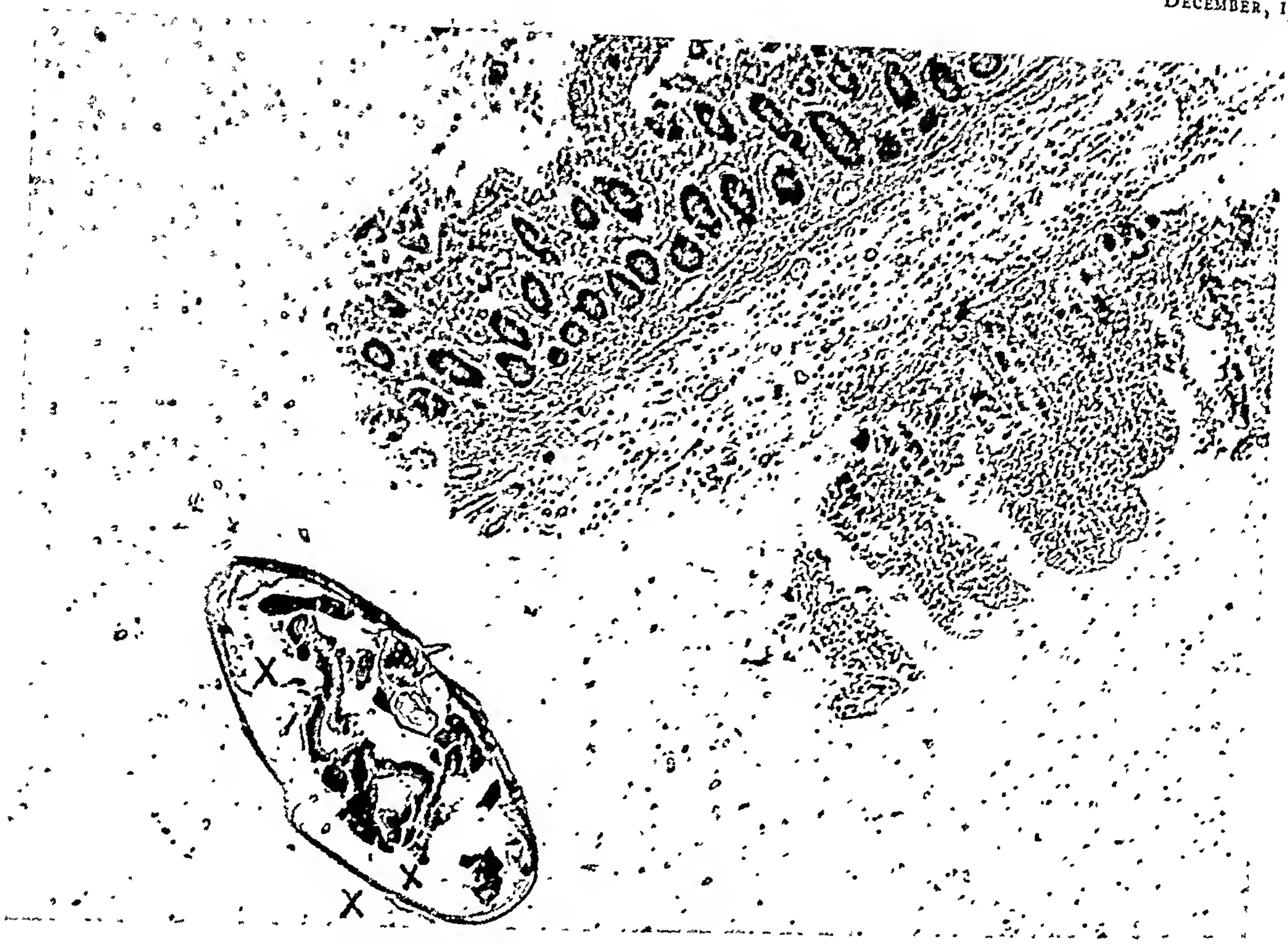

FIG. 2. Hookworm disease. Photomicrograph of jejunum taken from the region of the attached parasite. Portion of hookworm at *X*. The jejunal wall is slightly edematous. This section was taken from the specimen shown in Figure 1.

65 per cent of the patients we saw had clinical evidence of "hookworm disease." The rest were battle casualties or patients with other conditions in whom positive stools were found during routine studies.

The Americans treated for hookworm disease in our medical installation were in excellent health when they first arrived in the China-Burma-India Theatre of War. Approximately 80 per cent came from parts of the United States where hookworms were not a public health hazard. As we knew where and when they had traveled throughout India and Burma, it was easy to estimate when they were first exposed to the parasite. This, plus the clinical history, made it possible to judge the duration of the disease with considerable assurance. We felt reasonably confident, therefore, that the disease, as we saw it, was of recent origin. In 80 per cent the disease was believed to be less than three months in duration. The remaining cases were from six to eight months in duration; one patient was thought to have had the disease for approximately one year.

The recent past medical history in our patients was interesting. It was noteworthy how often the men remembered itching after lying in foxholes for several hours. Their descriptions of the "ground itch" were classical and it was by no means uncommon for them to volunteer that the itching was localized to that part of the body exposed to water or mud. The pruritus and dermatitis usually developed several hours after exposure and lasted from four to seven days.

Cough, too, was common. Indeed it occurred with such regularity in combat areas that men called it the "foxhole cough." It was potentially dangerous as it could expose their position to the enemy. The cough was usually dry and superficial, appearing one to two weeks after the "ground itch." The chests of many were examined

during the period of their gastrointestinal complaints, but no roentgen abnormalities were noted.

The onset of the gastrointestinal symptoms varied from six to twenty-five weeks after exposure. In many patients the disease was ushered in by an acute attack of nausea, vomiting, abdominal pain and diarrhea. In others, abdominal complaints developed gradually and were associated with marked weight loss and intractable diarrhea.

Pain was the most prominent intestinal complaint. It was usually epigastric and sometimes suggested peptic ulcer. In general, the pain was diffuse and was variously described as "burning" or "cramping" in character. As a rule, it was made worse by food.

Occasionally patients presented low grade fever for which no other cause but hookworm could be found. About half of the patients were tender over the upper abdomen, the tenderness being diffuse rather than localized. Hyperperistalsis on physical examination was the rule.

In contrast to the anemia described in chronic hookworm disease, the red blood cell counts and hemoglobin estimations were normal in all of our patients with but 3 exceptions. The latter were heavily infested and required morphine for relief of their abdominal distress. Of these, 2 had 11 grams of hemoglobin, the third, 13 grams.

About half of the patients had white blood cell counts of over 10,000, the average being about 15,000. The highest leukocyte count recorded was 41,000 in a patient with 70 per cent eosinophilia. Of the 68 individuals in whom differential white blood cell counts were obtained, 8 revealed less than 10 per cent eosinophiles. Thirty patients presented 11–30 per cent eosinophilia and the remaining 30, more than 30 per cent. The highest was 80 per cent recorded in a patient with 25,000 leukocytes. It was our impression that the eosinophiles

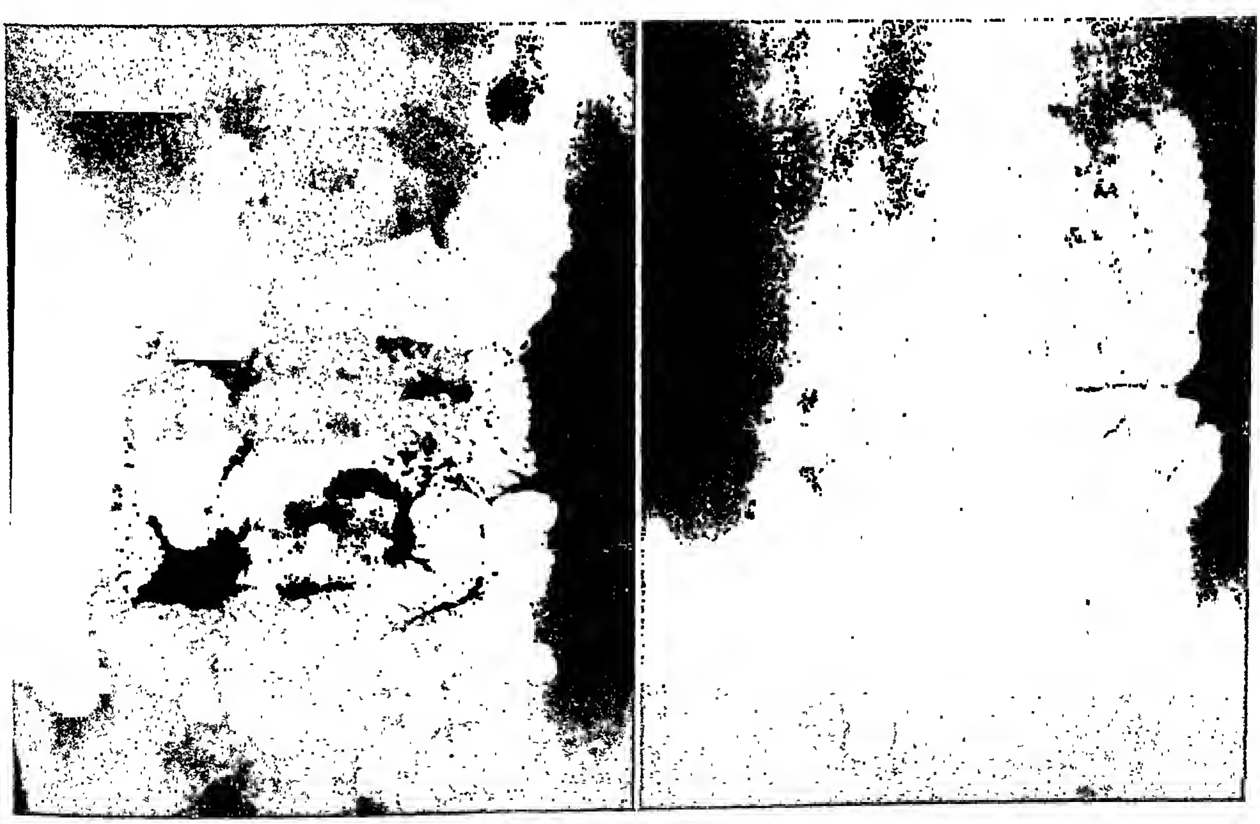

Fig. 3. Normal small intestine. Roentgenograms obtained at one-half and one and one-half hour intervals after distilled water and barium mixture taken by mouth. The barium stream is continuous. The caliber of the lumen is even and the mucosal folds are normal in size and distribution.

in the blood often varied directly with the severity of the clinical findings and the roentgen abnormalities. Usually the eosinophilia decreased as the patient improved.

The following case is reported because it demonstrates the classical sequence of events in hookworm disease. It is the earliest proved case in our experience.

CASE REPORT

On October 27, 1944, the patient, aged twenty-five, crawled under a mobile crane where he worked for about an hour while lying on his back. His shirt pulled out of his trousers exposing his skin to the ground. The patient's back was also exposed by a hole in his shirt. In about one hour he noticed itching. The following day a rash appeared in the skin areas exposed to the soil which lasted for three days.

Four days later, on October 31, the patient developed a cough which disappeared spontaneously in twelve days.

On November 12, sixteen days after the original exposure, he first noticed post-prandial fullness and began to vomit. Cramping abdominal pains also appeared which were made worse by eating. Four days later, on November 16, diarrhea was noted for the first time.

The patient was admitted to the hospital complaining of cramps and diarrhea on November 27, thirty-one days after his exposure. He was well nourished but exhausted. Mild upper abdominal tenderness was the only noteworthy clinical finding. Captain Arthur Rogers, the patient's ward physician, made the diagnosis of hookworm disease from the history alone. His opinion was verified by the hookworm ova found in saline suspensions of the stool obtained twenty-four hours later. At that time the patient's white blood cell count was 13,000 with 66 per cent eosinophiles; hemoglobin was 16.2 grams.

The patient was treated with tetrachlorethylene following which *Ankylostoma duodenale* and *Necator americanus* were identified in the stool. He made an uneventful recovery.

ROENTGEN EXAMINATION

Roentgen Technique. The gastrointestinal studies were done in the morning, the patient having fasted after midnight. Five ounces of barium suspended in 5 ounces of distilled water were used routinely. Roentgenoscopic observations were made in the erect and horizontal positions following which the patient was examined at thirty to forty-five minute intervals, depending upon the findings. Roentgenograms were obtained routinely every half hour for the first two hours and every hour subsequently. In most instances the examinations were completed at the end of three hours.

Roentgen Observations before Treatment. Sixty per cent of the patients with hookworm infestation revealed gastrointestinal abnormalities on roentgen examination. As a rule, the changes were proportional to the severity of the patient's illness. Individuals with mild infestations showed few abnormalities, if any, whereas those with definite distress showed striking changes.

The esophagus was usually normal in patients with ankylostomiasis. Aerophagia and phrenospasm were noted but their incidence was not unusual. Esophageal irritability was never observed in this series.

The stomach was also essentially negative. Exaggerated rugal folds and increased tone were seen occasionally. Gastric emptying was usually normal, or, in rare instances, slightly delayed.

The duodenal bulb was regularly normal. Occasionally, in the seriously ill, it was irritable but it was rarely tender and spastic. In some the mucosal folds seemed prominent but the change was never striking.

The findings were different in the third and fourth portions of the duodenum where marked abnormalities were common in the seriously ill. Increased tone manifest by narrowing of its lumen, and irritability were the rule. They revealed mucosal distortions which varied with the severity of the infestation. Appearing normal in patients with few symptoms, the folds became increasingly thick and distorted as the disease progressed. In many they were spaced irregularly and showed noteworthy variations in size and shape (Fig. 4).

Occasionally the distal duodenum seemed to lose its tone completely. Momentary periods of dilatation were noted at which

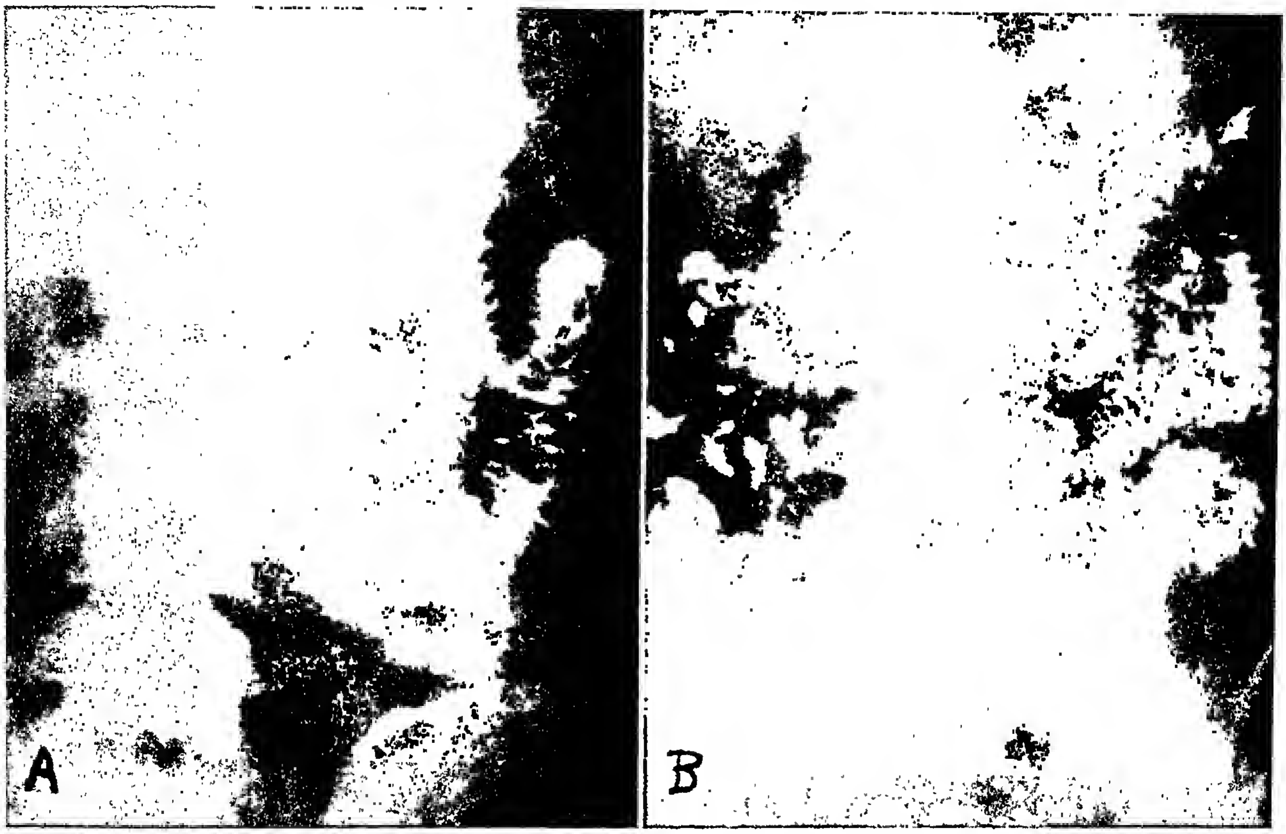

Fig. 4. Hookworm disease. Roentgenograms obtained one hour and two and one-half hours after barium meal taken orally. There is considerable delayed motility and duodenal dilatation in *A*. The mucosal pattern is distinctly abnormal. *B* reveals diffuse irritability of the small intestine with long areas of peristaltic contraction and segmentation. Chief complaints were nausea, vomiting, and severe cramps for six weeks. White blood cell count 40,000, with eosinophiles 70 per cent. (Patient was raised in Nebraska.)

time the third and fourth portions of the duodenum ballooned out and appeared sausage shaped. This was a transient phenomenon which was followed promptly by the hypertonic pattern. The change was unpredictable and occurred more often in the jejunum.

Reverse peristalsis was rarely observed in this portion of the small intestine.

Jejunal tenderness was the earliest manifestation of hookworm disease. It was almost always present and was elicited with ease by direct pressure under roentgenoscopic guidance. It occurred with enough regularity to suggest the clinical diagnosis in patients with minor roentgen findings. Whereas the distal duodenum and distal jejunum were often tender also, the area of maximum discomfort was confined usually to the proximal half of the jejunum.

Narrowing of the intestinal lumen and mucosal distortion characterized the roentgen findings. The tone varied directly with the severity of the clinical findings, the lumen approaching one-half to one-third its normal dimensions. Often normal in asymptomatic individuals, the intestine appeared increasingly irritable and intolerant of the barium as the complaints progressed (Fig. 5). With progression these changes involved more and more of the intestine until, in the seriously ill, the entire jejunum and portions of the ileum were involved. Shortening and narrowing of the lumen of the small intestine were also noteworthy in well developed infestations (Fig. 6).

Roentgenoscopically, both segmental and peristaltic contractions were increased in intensity. The normal gentle sway of the small intestine was often replaced by active pendulum movements which were "accordion like" and seen with ease. In rare instances a "cog-wheel" appearance was ob-

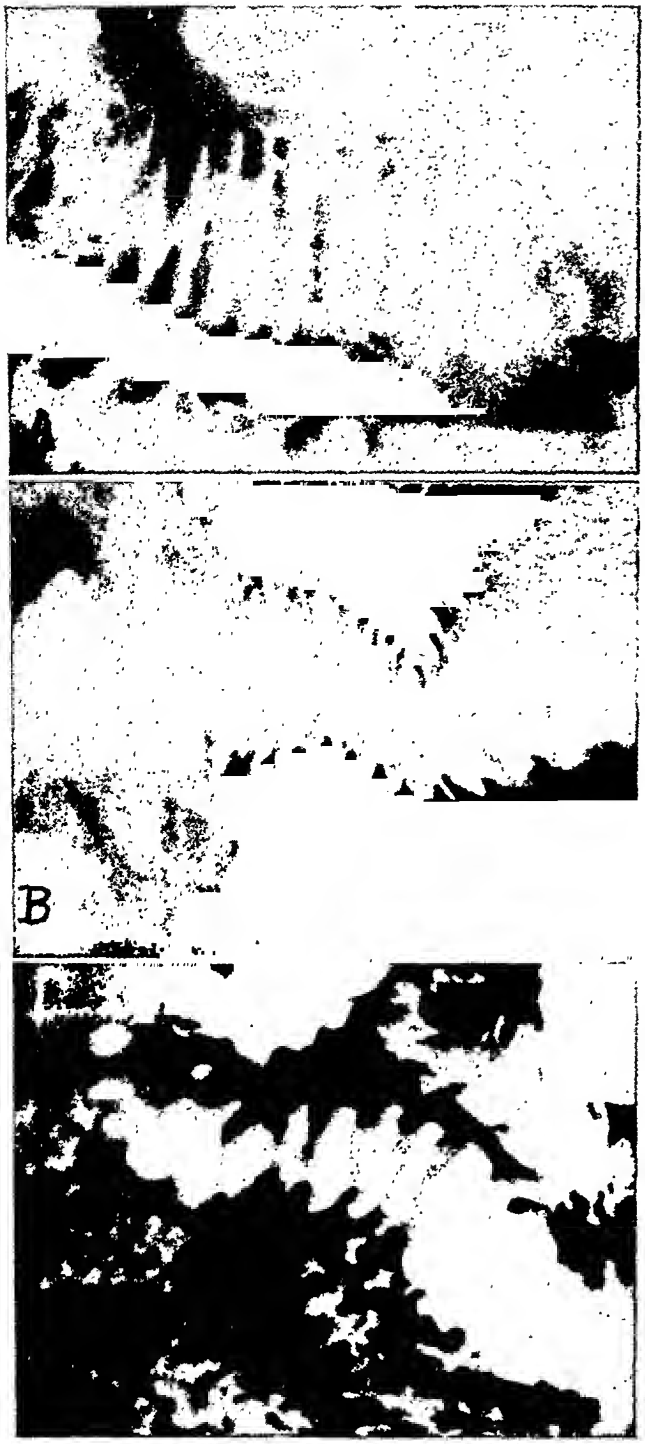

Fig. 5. Hookworm disease. Close-up reproductions of the proximal jejunum taken from the small intestinal studies of 3 patients with hookworm disease. The mucosal folds in *A* are wider and higher than normal; in *B* they are irregularly spaced and point irregularly in all directions; *C* reveals much thicker mucosal folds which are widely separated from each other in one segment.

served roentgenographically which was probably an actual record of a segmental contraction recorded while the film was being exposed (Fig. 7).

Peristalsis was vigorous and rapid. The segments of contracted intestine along the path of the propelling peristaltic waves were narrower and longer than those seen in healthy individuals. The intestine seemed constantly active and unable to relax. Occasionally transient periods of marked relaxation were noted when the jejunum appeared atonic and ballooned out, an appearance described above in the distal duodenum (Fig. 8). Here, too, inhibition of intestinal tone was momentary and was followed immediately by active contractions.

The mucosal folds of the jejunum revealed striking variations. Normally 1 to 2 mm. in width and about the same distance apart, the valvulae conniventes in well developed hookworm disease were two or three times as wide and spaced irregularly apart up to 5 or 7 mm. The folds appeared thick and irregular rather than slender and neat (Fig. 5, 9 and 10). The ease and speed with which their form and direction changed made one confident they were manifestations of an irritable muscularis mucosae rather than organic infiltrations of the mucous membrane (Fig. 14). Also noteworthy were their uneven increase in height and the irregular manner in which they dipped into the column of barium. Instead of small groups of mucosal folds lying parallel there were areas where neighboring folds pointed irregularly in all directions (Fig. 5). The result was anything but the continuous even barium shadow usually seen roentgenographically in the normal jejunum (Fig. 3).

The ileum usually revealed nothing abnormal. About half of the patients in this group showed increased ileal tone (Fig. 9 and 11). In approximately 40 per cent, the barium transit time was slow, being over three hours. Ileal stasis with marked segmentation and bolus formation were not the rule but were not uncommon.

Of particular interest were the mucosal folds in the ileum. Normally low, 1 or 2 mm. high, and widely separated, they were occasionally prominent and closely aligned

Fig. 6. Hookworm disease. Roentgenograms obtained fifteen minutes (*A*) and one hour (*B*) after oral administration of barium. The entire small intestine is irritable and seems unable to relax. The mucosal folds are wide, irregular in height, and unevenly spaced. Chief complaint was post-prandial epigastric distress for three weeks. White blood cell count 18,000, with 48 per cent eosinophiles. (Patient was raised in New York State.)

in hookworm disease (Fig. 12). In this the mucosal pattern of the terminal ileum mimicked that of the normal jejunum. When present, it was invariably associated with marked jejunal changes.

Roentgen Observations after Treatment. Twenty-eight patients were examined from one to four times after treatment. A few were studied two to four weeks after treatment; many more were re-examined at the end of two to six months.

Two patients with jejunal tenderness but no roentgen abnormalities were re-examined three and ten weeks after treatment. The gastrointestinal tracts were normal and the tenderness gone in both. Neither was very ill when first seen, however.

Fourteen patients with moderately severe clinical complaints and moderate roentgen changes were re-examined one to three months after therapy. In 3 the gastrointestinal tract returned to normal in one to two months (Fig. 10). Six patients revealed roentgen evidence of improvement one to three months after treatment. Three were unchanged after one to three months

Fig. 7. Hookworm disease. "Cog-wheel" jejunal pattern. This was occasionally seen and probably represents a record of a rhythmic segmental contraction obtained during the time the film was being exposed. One might consider it a kymogram of a pendulum movement.

FIG. 8. Hookworm disease. Roentgenogram obtained one hour after barium by mouth. Note dilated jejunal loop with flat mucosal folds. Chief complaint was abdominal cramps. Hemoglobin 13 grams; 60 per cent eosinophiles. (Patient was raised in Iowa.)

and 2 were definitely worse three months later. Clinically all but the last 2 were considerably improved or entirely well at the time the follow-up study was done.

Twelve seriously ill patients were reexamined three to six months after completing an adequate therapeutic course. Five showed marked improvement in the roentgen appearance of the intestine in three months. Of the latter, one was well clinically, and the second was improved but not symptom free. In 3, the intestinal distortion was worse four to six months after treatment. One of the latter was much improved clinically, one was moderately improved, and the third unchanged. In such instances repeated stool examinations occasionally revealed ova even though they had been negative following the first therapeutic course.

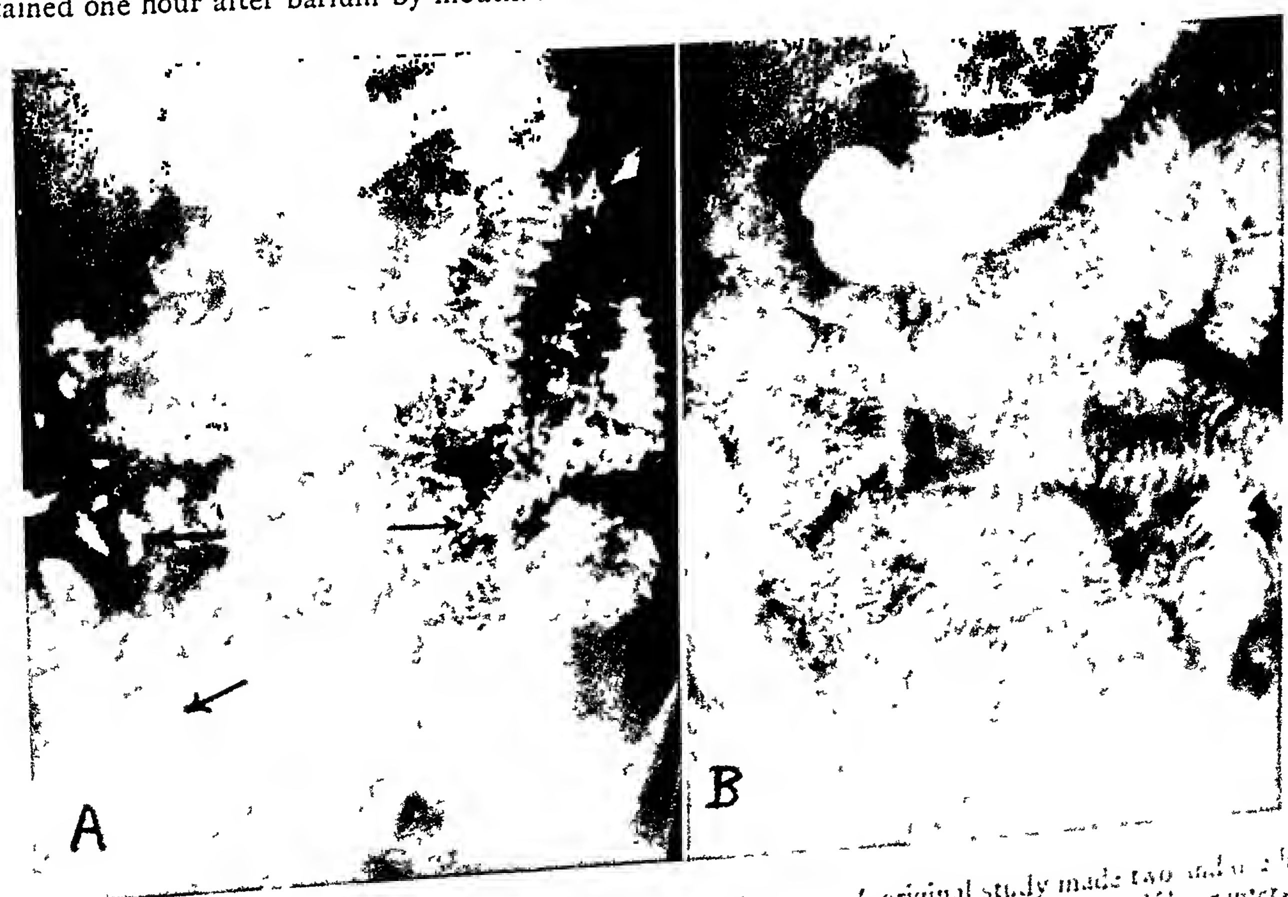

FIG. 9. Hookworm disease. Same patient as described in Figure 4. *A*, original study made two and one-half hours after barium by mouth. *B*, re-examination five months later at same two and one-half hour interval. Patient clinically well at this time, but stools still positive. Note the more adequate relaxation of the small intestine. The mucosal folds are still long, thick, and irregularly spaced.

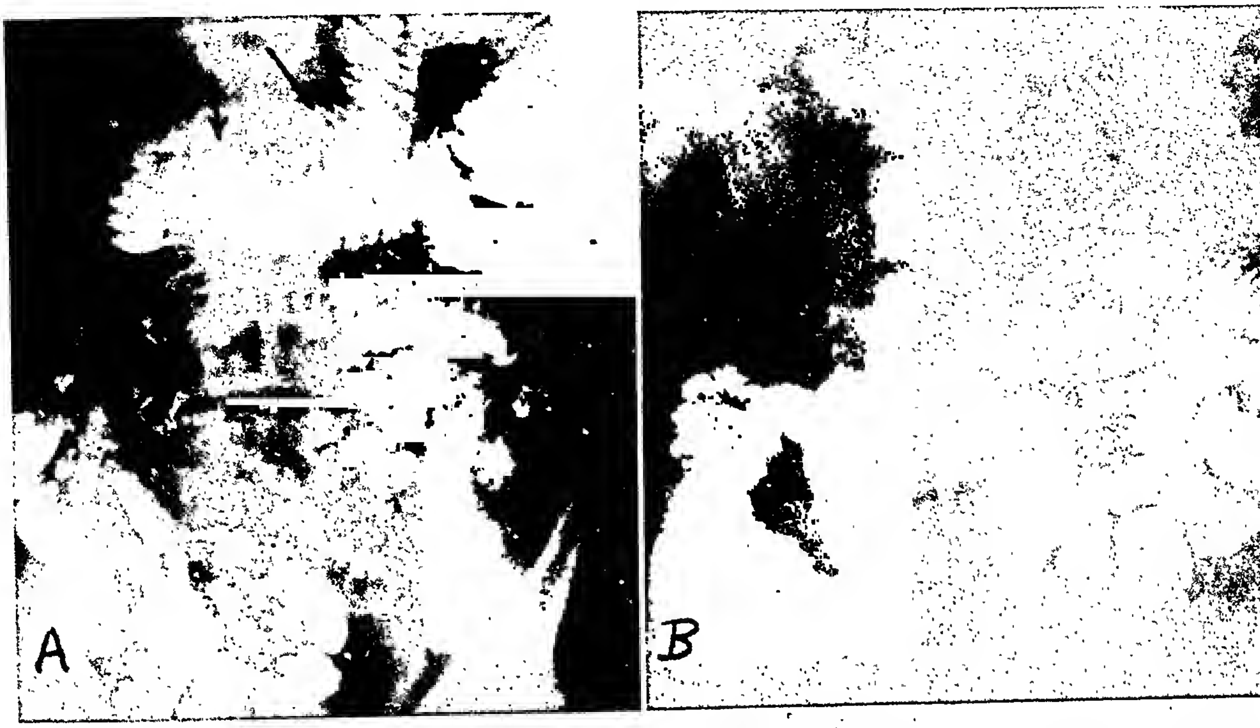

Fig. 10. Hookworm disease. Original small intestinal study in *A*. Roentgenogram obtained one and one-half hours after ingested barium meal. Note dilated jejunal loops with highly accentuated mucosal folds. The distal jejunum and proximal ileum reveal marked contraction, an appearance which could be attributed to failure of relaxation. Chief complaints were generalized abdominal pain, nausea, and vomiting of four weeks' duration. White blood cell count, 7,600, with 21 per cent eosinophiles. *B*, four months later, small intestinal pattern essentially normal at same one and one-half hour interval. Patient well except for slight abdominal tenderness. (Patient raised in New York State.)

With improvement the jejunal tenderness diminished and then disappeared. Whereas the intestinal pattern often remained abnormal, it seemed less irritable and spastic. Motility, too, tended to return to normal, and in some actually became rapid (Fig. 13). The greatest delay in improvement was noted in the mucosal folds, which often remained distorted for months after patients were apparently cured.

Occasionally, following treatment, the intestinal pattern changed abruptly from the normal to abnormal. Occurring one to one and a half hours after the barium meal was ingested, the change was characterized by hyperperistalsis, excess segmental contraction and mucosal distortion, all manifestations of failure of relaxation. The evidence suggested that the sudden change we observed might be due to derangement of reflexes which normally controlled intestinal activity. Perhaps fatigue of a previously damaged intramural nervous system was responsible for the abrupt variations described above.

DISCUSSION

Complete gastrointestinal studies were obtained in 10 healthy members of our command as soon as we arrived in India (Fig. 3). Anticipating nutritional deficiencies and intestinal diseases, we did this to have controls available for future reference. About sixteen months later these men were re-examined clinically and roentgenologically; no changes were found. Viewed in the light of these control studies, it seemed reasonable to conclude that the changes we saw in hookworm disease were not due to diet alone.

Krause and Crilly[5] attributed the intestinal distortions to "certain dietary factors," feeling that neither the actual presence of worms nor anemia was responsible for the changes. Golden, discussing their paper, suggested that the hookworms

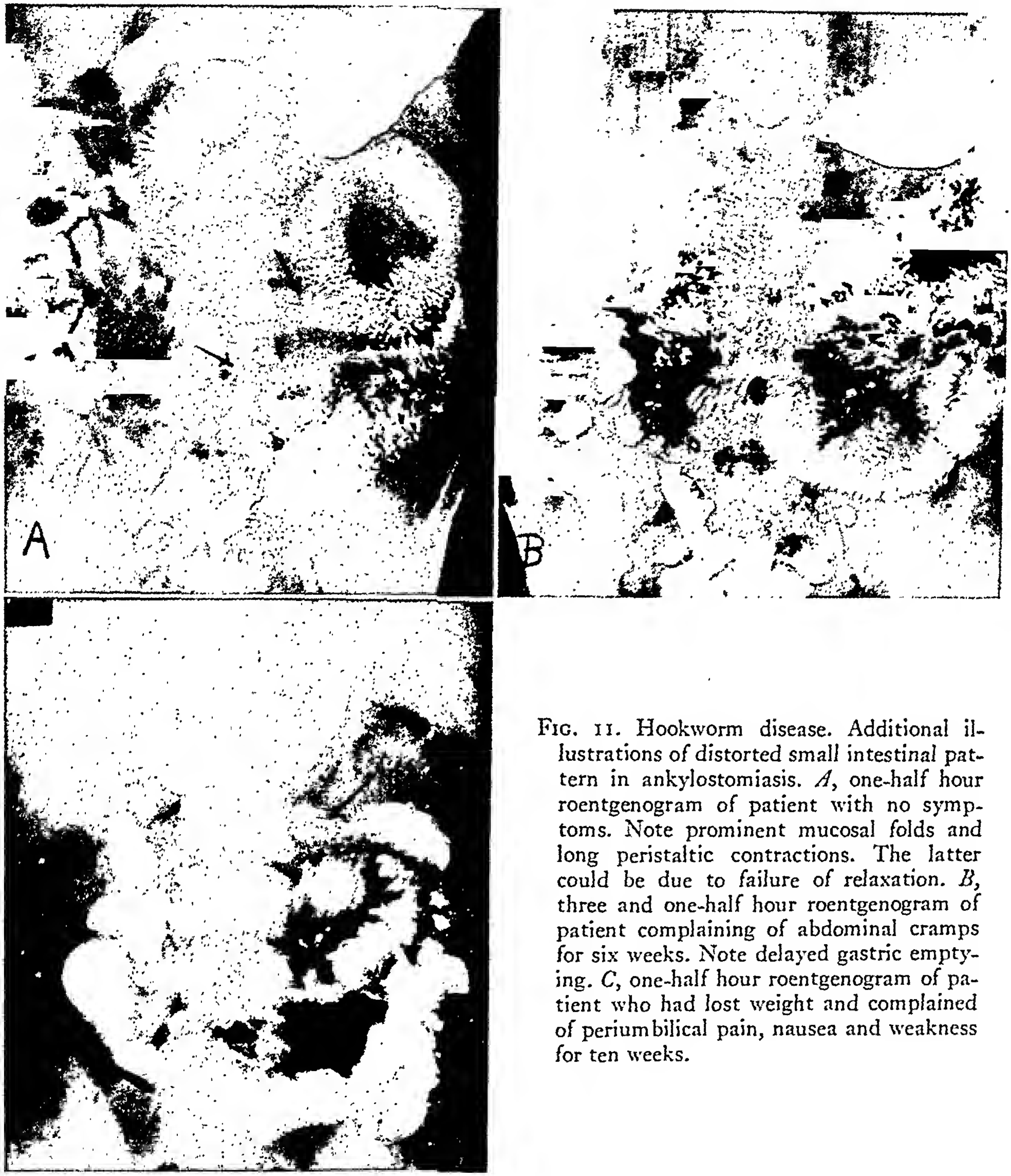

Fig. 11. Hookworm disease. Additional illustrations of distorted small intestinal pattern in ankylostomiasis. *A*, one-half hour roentgenogram of patient with no symptoms. Note prominent mucosal folds and long peristaltic contractions. The latter could be due to failure of relaxation. *B*, three and one-half hour roentgenogram of patient complaining of abdominal cramps for six weeks. Note delayed gastric emptying. *C*, one-half hour roentgenogram of patient who had lost weight and complained of periumbilical pain, nausea and weakness for ten weeks.

themselves, as well as nutritional disturbances, might have been the cause.

Many of our patients were below their normal weight when we first saw them. They revealed no clinical evidence of malnutrition or anemia; the former could have been present but not recognized. The same could have been true of hypoproteinemia which we did not exclude because of conditions beyond our control. Admitting all these factors (anemia, nutritional deficiencies, hypoproteinemia, the actual presence of the hookworms) to be important in the production of the intestinal changes seen before treatment, it was difficult to explain why the distorted roentgen pattern persisted after treatment in many patients who were well clinically.

Reports of cases of hookworm disease found in a limited review of the literature

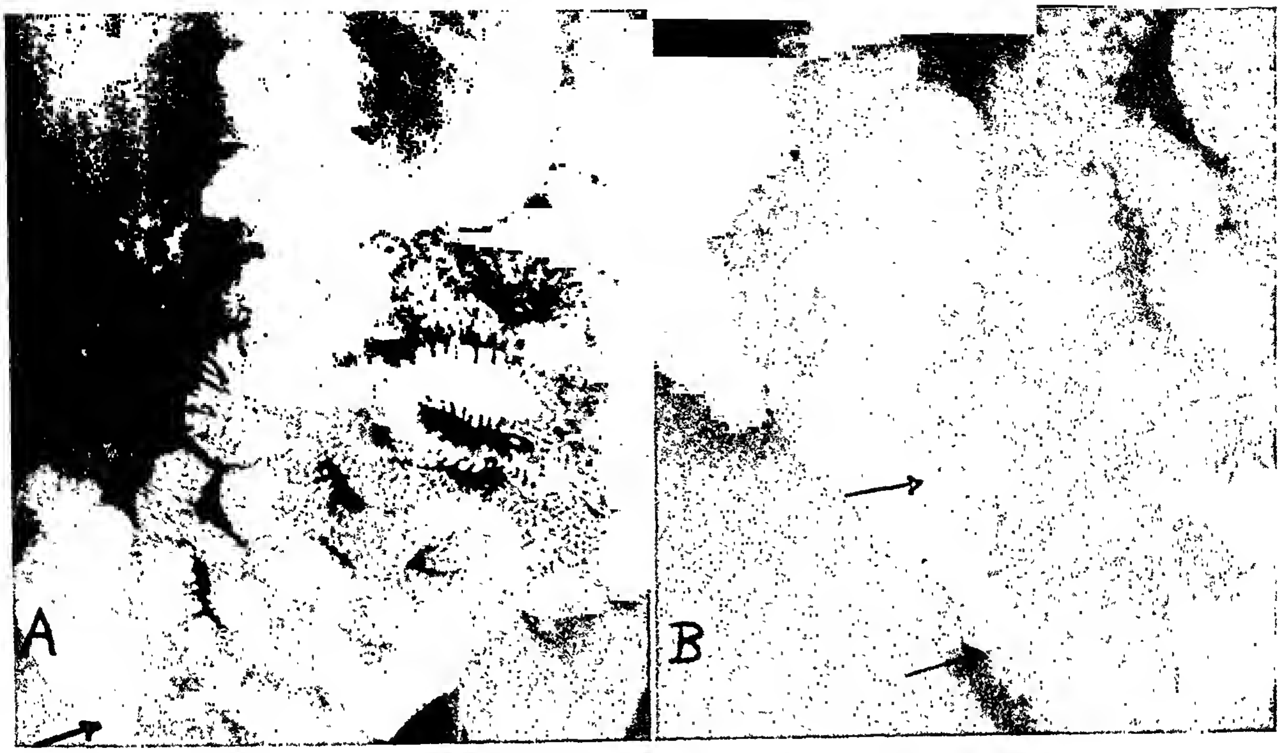

FIG. 12. Hookworm disease. Roentgenogram obtained one and one-half hours after oral ingestion of barium meal. Note continuous stream of barium in *A*. The mucosal folds are clearly visualized throughout the ileum. Enlargement of ileocecal portion of *A* seen in *B* reveals the prominent and wide mucosal folds to better advantage.

FIG. 13. Hookworm disease. *A*, original oral barium meal study. Roentgenogram obtained one-half hour after barium meal. The barium stream is continuous but the bowel is hypertonic, narrow, and shortened. The mucosal folds are coarse and irregular in height, width, and spacing. Chief complaints were nausea, postprandial abdominal cramps, and right upper quadrant pain of ten weeks' duration. White blood cell count 6,700, with 50 per cent eosinophiles; hemoglobin 14.5 gm. *B*, three months later, roentgenogram taken at same one-half hour interval reveals rapid transit time with barium in splenic flexure. The small intestine is less hypertonic, but still abnormal. (Patient was raised in West Virginia.)

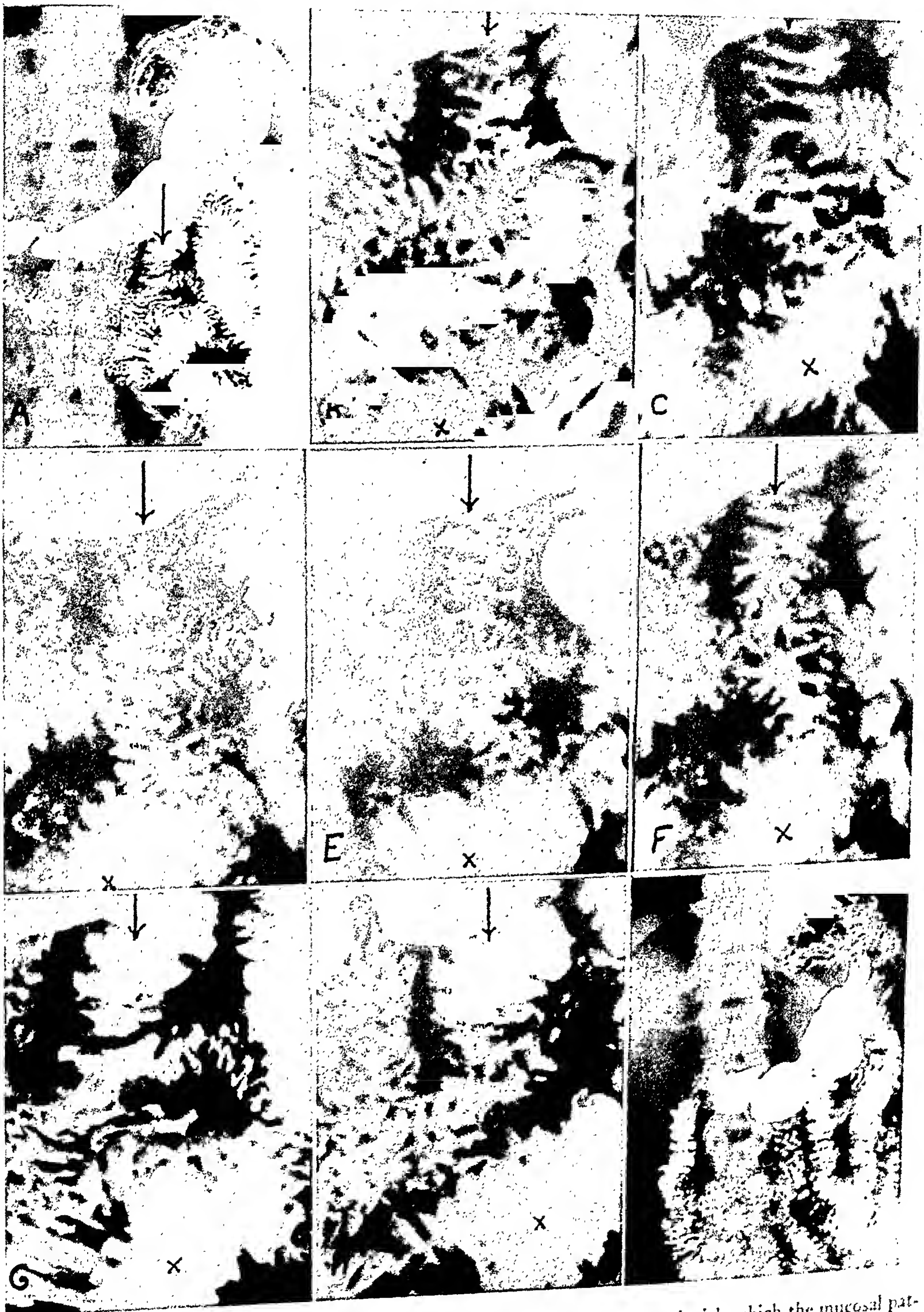

FIG. 14. Hookworm disease. Series of exposures made to demonstrate the speed with which the mucosal pattern can change. Roentgenograms were obtained at about ten to fifteen second intervals. *A* is a reproduction of one of this series of 14 by 17 inch exposures shown to orient the reader. The one loop of jejunum chosen to demonstrate the mucosal activity is indicated by the arrow. The subsequent reproductions are close-up

say little about the histopathlogical characteristics of the wall of the small intestine. Mention was made of "hemorrhage, eosinophilic infiltration, and edema," but nothing definite was gathered concerning the thickness of the intestine or the condition of its intramural nervous system.

Golden,[2] reviewing the physiology of the small intestine, called attention to the importance of the latter. He commented upon the delicate balance that exists between the sympathetic and parasympathetic nervous systems. He presented numerous illustrations of "disordered motor function" among which he included the distorted pattern of nutritional disturbances. Of unusual interest and importance were his comments about the pathology of the intramural nervous system and the "vacuolization of nerve cells in both myenteric and submucosal plexuses" demonstrated with special stains in a patient with nontropical sprue. Of equal significance were Ingelfinger and Moss's[4] observations in sprue where they noted that the intramural nervous apparatus was unable to liberate active acetylcholine and that the injection of acetylcholine produced intestinal movements.

It was our impression that the mucosal changes seen in hookworm disease were in the main due to an abnormal intramural nervous system. We felt that disturbances in reflex arcs rather than actual thickening of the wall of the intestine were responsible for the distorted mucosal pattern. It was found difficult to picture an indurated intestine changing its mucosal appearance and lumen with the speed that characterized the small intestine in this study (Fig. 14).

The roentgen observations tend to support this postulate. If the intramural nervous system were damaged one could understand why distorted mucosal patterns persisted after the hookworms were destroyed by vermifuges. Conversely, if the intramural nervous system remained intact or but slightly damaged it would explain why 40 per cent of patients with hookworm disease revealed no roentgen evidence of distorted mucosal folds. The latter observation lends further support to the idea that the presence of hookworms alone is not responsible for the mucosal changes. Finally, it would explain why the disordered motor function pattern differed from patient to patient, for if the degree of involvement of the intramural nervous system varied it would seem proper for the intestinal pattern to vary.

What damaged the intramural nervous system, if indeed it was damaged, remained a moot problem. We believe it highly possible that the hook-like teeth of the parasites were to blame. Cutting into the mucous membrane at the site of their embedded buccal capsule they might readily have interfered with the elaborate network of nerve cells and fibers which extend to every portion of the intestine from the subserosal, Auerbach's, the deep muscular, and Meissner's plexuses. That toxins, too, might have played a part cannot be denied; the fact that an immunity to hookworm disease in dogs has been produced experimentally implies that this is a possibility for it suggests the presence of an endotoxin. The latter seems unlikely, however.

SUMMARY

1. Over 125 American troops with proved ankylostomiasis were examined roentgenologically for gastrointestinal changes.

2. Approximately 60 per cent revealed roentgen abnormalities in the small intestine.

3. Changes in the small intestine were

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enlargements of this one loop which are arranged in the order in which they were taken. The mucosal folds are not static. From roentgenogram to roentgenogram definite changes in height, width, and spacing occur which could not happen were the mucosa and submucosa thickened enough to have caused the distortion. Similar intestinal activity can be observed at *X* which is a lower jejunal loop. The film in the lower right hand corner was taken immediately after the series of exposures was completed.

noted within one month after exposure to the parasites.

4. Whereas the intestinal abnormalities demonstrable by roentgen methods appeared first in the proximal jejunum, they spread into the distal duodenum, distal jejunum, and throughout the ileum.

5. The changes were those of "disordered motor function," characterized by excessive peristaltic and segmental contractions with distortion of the mucosal pattern.

6. Improvement in the roentgen manifestations of the disease occurred early in some cases and in many others was delayed. Not infrequently the abnormal changes persisted for months after the patient was well clinically.

7. Causes for the intestinal changes in hookworm disease are discussed and the possibility of their being in part due to a damaged intramural nervous system is postulated.

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Grateful acknowledgment is due Dr. Eugene P. Pendergrass and Dr. Ross Golden who patiently answered our questions and made many helpful suggestions in the preparation of this manuscript. The illustrations were prepared by the 1st Detachment, Museum and Arts Detachment, to whom we are also indebted and now expresss our sincere appreciation.

REFERENCES

1. CHANDLER, A. C. Introduction to Parasitology. Sixth Edition. John Wiley & Sons, New York, 1940.
2. GOLDEN, Ross. Radiologic Examination of the Small Intestine. J. B. Lippincott Co., Philadelphia, 1945.
3. HENDERSON, W. F. Antiperistalsis in duodenum; presumptive sign of intestinal parasitosis. *J. Am. M. Ass.*, 1925, *84*, 493–494.
4. INGELFINGER, F. J., and MOSS, R. E. Motility of the small intestine in sprue. *J. Clin. Investigation*, 1943, *22*, 345–352.
5. KRAUSE, G. R., and CRILLY, J. A. Roentgenologic changes in the small intestine in the presence of hookworm. AM. J. ROENTGENOL. & RAD. THERAPY, 1943, *49*, 719–730.
6. STRONG, R. P. In: Stitt's Diagnosis, Prevention and Treatment of Tropical Diseases. Blakiston Co., Philadelphia, 1943.
7. YENIKOMSHIAN, H. A., and SHEHADI, W. H. Duodenal ulcer syndrome caused by ankylostomiasis. AM. J. ROENTGENOL. & RAD. THERAPY, 1943, *49*, 39–48.

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ROSS GOLDEN

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EDITORIAL

FIFTIETH ANNIVERSARY OF THE DISCOVERY OF THE ROENTGEN RAY

SCIENCE dawned though late upon the earth and the science of roentgenology much, much later. The steady sure progress in human endeavor was never better exemplified than in the story of the forefathers of Röntgen; each in his turn added a bit of knowledge which ultimately resulted in the discovery of the roentgen ray, a discovery of unparalleled fruitfulness in the advancement of benefit to the human race, which had led us steadily but surely up "the steep ascent from the unknown to the known." Within the span of fifty years we have progressed from a faint flicker of the cathode ray upon the fluorescent screen in Röntgen's laboratory in Würzburg to the fall of the atomic bomb upon Hiroshima. Between these two events there has emerged from the careful thought and experimentation of many minds and hands over the, world a well ordered road map of experience not only in the diagnostic and therapeutic aspect of roentgenology but also in the use of the roentgen ray in many other fields.

We are too close to the events which accompanied the development of the atomic bomb to have a full realization and appreciation of its portent. However, it is well to survey some of the tremendous advances that have been made not only in medicine but also in chemistry and physics since the discovery of the roentgen ray. Perhaps no single episode which has resulted from a scientific effort has so influenced the progress of the human race. By its use we have opened a new era not only in the diagnostic but also in the therapeutic approach to disease.

The employment of the roentgen ray in its earliest stages gave us a new conception of the skeletal structures and made possible the diagnosis of inflammatory diseases and tumors which involve this system, and in these later years the roentgen ray has been used in the determination of bone dyscrasias which result from endocrine and metabolic disturbances. Its employment in the normal physiology of growth and development is comparatively recent and is of untold importance. Without the roentgen ray the whole recent advance in neurological surgery would not have been possible. As an ancillary in the diagnosis of tumors and diseases of the brain and spinal cord a new chapter in surgery has been written. The great advances that have been made in the physiology of the respiratory system as well as in the diagnosis of diseases of the respiratory system are almost incredible. A formidable diagnostic aid has been added to the stethoscope and one might say has almost replaced it as a diagnostic instrument.

As a result of the peculiar fitness of the roentgen ray for the early diagnosis of tuberculosis we have brought this disease almost within the limits of control, though the roentgen ray as a method of study of diseases of the chest was not generally accepted until 1912. Without the roentgen ray the enormous progress that has been made in thoracic surgery would have been delayed years, and yet within the present generation by its use the surgical approach not only to diseases of the respiratory system itself but to the circulatory system as well has been made possible.

The steady advances in our knowledge of the normal physiology of the gastrointestinal tract as well as its pathology have been made possible by the use of the roentgen ray. With its employment in diseases

of the genitourinary tract the diagnosis of urological conditions has almost approached an exact science.

Shortly after the discovery of the roentgen ray the possibility of using it therapeutically became evident and within a comparatively short time following the announcement of the discovery, superficial skin lesions and cancers of the skin were treated with roentgen radiation. Since those early days we have seen a steady progress in the use of the roentgen ray in the treatment of various diseases, but particularly neoplastic disease. This progress has been a sure one and has been made possible by the continuous improvement in the construction of tubes and mechanical devices for measuring the quality of the roentgen radiation administered. No longer do we rely upon inadequate or unsatisfactory equipment in this respect and with the technical advances made in the construction of machines the end in the radiation therapy of tumors is not yet. The advances in the use of the roentgen ray as a therapeutic agent have been so important that we now have specialization in radiotherapy.

There is no branch of medicine which has not benefited by the employment of the roentgen ray. With its use the workers in physics and chemistry have unlocked the wicket gates of nature; they have explored the realm of the unknown and have unraveled many of its secrets and thus have been able to harness additional forces of nature.

The recent experimental work with the roentgen ray has opened an entirely new chapter in atomic energy, the possibilities of which are already being explored. Some hint of the outcome of these explorations is given in a thought-provoking paper on "Utilization of Antibody for the Localization of Metals and Dyes in the Tissues" found elsewhere in this issue.

In the realm of industry we have seen revolutionary changes as the result of the employment of the roentgen ray in the spectral analysis of metals, eliminating to a marked degree the trial and error methods which had hitherto been followed. Such revolutionary changes have also resulted from the roentgenologic examination of the various products of industry during their process of manufacture and after their completion.

The whole history of the roentgen ray from the day of its discovery until the present time is one of steady sure progress in every field of scientific endeavor. With this issue of the Journal we commemorate the Fiftieth Anniversary of the discovery of the roentgen ray—one of man's greatest achievements.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

UNITED STATES OF AMERICA

AMERICAN ROENTGEN RAY SOCIETY
Secretary, Dr. H. Dabney Kerr, University Hospital, Iowa City, Iowa. Annual meeting: 1945, canceled.

AMERICAN COLLEGE OF RADIOLOGY
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago.

SECTION ON RADIOLOGY, AMERICAN MEDICAL ASSOCIATION
Secretary, Dr. U. V. Portmann, Cleveland Clinic, Cleveland, Ohio. Annual meeting: 1945, canceled.

ARKANSAS RADIOLOGICAL SOCIETY
Secretary, Dr. J. S. Wilson, Mack Wilson Hospital, Monticello, Ark. Meets every three months and also at time and place of State Medical Association.

RADIOLOGICAL SOCIETY OF NORTH AMERICA
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: 1945, cancelled.

RADIOLOGICAL SECTION, BALTIMORE MEDICAL SOCIETY
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

SECTION ON RADIOLOGY, CALIFORNIA MEDICAL ASSOCIATION
Secretary, Dr. Gordon G. King, 3700 California St., San Francisco 18, Calif.

RADIOLOGICAL SECTION, CONNECTICUT MEDICAL SOCIETY
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets bi-monthly on second Thursday, at place selected by Secretary. Annual meeting in May.

SECTION ON RADIOLOGY, ILLINOIS STATE MEDICAL SOCIETY
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

RADIOLOGICAL SECTION, LOS ANGELES COUNTY MEDICAL ASSOCIATION
Secretary, Dr. Roy W. Johnson, 1407 S. Hope St., Los Angeles, Calif. Meets on second Wednesday of each month at the County Society Building.

RADIOLOGICAL SECTION, SOUTHERN MEDICAL ASSOCIATION
Secretary, Dr. Roy G. Giles, Temple, Texas.

BROOKLYN ROENTGEN RAY SOCIETY
Secretary, Dr. Leo Harrington, 880 Ocean Ave., Brooklyn, N.Y. Meets monthly on fourth Tuesday, October to April.

BUFFALO RADIOLOGICAL SOCIETY
Secretary, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months.

CHICAGO ROENTGEN SOCIETY
Secretary, Dr. F. H. Squire, 1754 W. Congress St., Chicago 12, Ill. Meets second Thursday of each month October to April inclusive at the Palmer House.

CINCINNATI RADIOLOGICAL SOCIETY
Secretary, Dr. Samuel Brown, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

CLEVELAND RADIOLOGICAL SOCIETY
Secretary, Dr. Carroll C. Dundon, 2065 Adelbert Road, Cleveland 6, Ohio. Meetings at 6:30 P.M. on fourth Monday of each month from October to April.

DALLAS-FORT WORTH ROENTGEN STUDY CLUB
Secretary, Dr. X. R. Hyde, Medical Arts Bldg., Fort Worth, Texas. Meetings held in Dallas on odd months and in Fort Worth on even months, on third Monday, at 7:30 P.M.

DENVER RADIOLOGICAL CLUB
Secretary, Dr. A. Page Jackson, Jr., 1612 Tremont Place, Denver, Colo. Meets third Friday of each month at Denver Athletic Club.

DETROIT ROENTGEN RAY AND RADIUM SOCIETY
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

FLORIDA RADIOLOGICAL SOCIETY
Secretary, Dr. J. F. Pitman, Blanch Hotel Annex, Lake City, Fla. Meetings in May and November.

GEORGIA RADIOLOGICAL SOCIETY
Secretary, Dr. James J. Clark, 478 Peachtree St., Atlanta, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

RADIOLOGICAL SOCIETY OF KANSAS CITY
Secretary, Dr. Arthur B. Smith, 800 Argyle Bldg., Kansas City, Mo. Meets third Thursday of each month.

ILLINOIS RADIOLOGICAL SOCIETY
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meets three times a year.

INDIANA ROENTGEN SOCIETY
Secretary, Dr. H. C. Ochsner, Methodist Hospital, Indianapolis. Meets annually second Sunday in May.

IOWA X-RAY CLUB
Secretary, Dr. Arthur W. Erskine, 326 Higley Bldg., Cedar Rapids, Iowa. Luncheon and business meeting during annual session of Iowa State Medical Society. Special meetings by announcement.

KENTUCKY RADIOLOGICAL SOCIETY
Secretary, Dr. W. C. Martin, 321 W. Broadway, Louisville. Meets annually in Louisville on first Saturday in Apr.

LONG ISLAND RADIOLOGICAL SOCIETY
Secretary, Dr. Marcus Wiener, 1430-48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:30 P.M.

LOUISIANA RADIOLOGICAL SOCIETY
Secretary, Dr. J. R. Anderson, 1130 Louisiana Ave., Shreveport. Meets annually during Louisiana State Medical Society Meeting.

MICHIGAN ASSOCIATION OF ROENTGENOLOGISTS
Secretary, Dr. E. M. Shebesta, 1429 David Whitney Bldg., Detroit. Three meetings a year, Fall, Winter, Spring.

MILWAUKEE ROENTGEN RAY SOCIETY
Secretary, Dr. C. A. H. Fortier, 231 W. Wisconsin Ave., Milwaukee, Wis. Meets monthly on second Monday at University Club.

MINNESOTA RADIOLOGICAL SOCIETY
Secretary, Dr. Annette T. Stenstrom, 1218 Medical Arts Bldg., Minneapolis, Minn. One meeting a year at time of Minnesota State Medical Association.

NEBRASKA RADIOLOGICAL SOCIETY
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month, at 6 P.M. at either Omaha or Lincoln.

NEW ENGLAND ROENTGEN RAY SOCIETY
Secretary, Dr. George Levene, Massachusetts Memorial Hospitals, Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

NEW HAMPSHIRE ROENTGEN RAY SOCIETY
Secretary, Dr. Richard C. Batt, Berlin, N. H. Four meetings a year.

RADIOLOGICAL SOCIETY OF NEW JERSEY
Secretary, Dr. H. R. Brindle, 501 Grand Ave., Asbury Pk. Meets annually at time and place of State Medical Society. Mid-year meetings at place chosen by president.

NEW YORK ROENTGEN SOCIETY
Secretary, Dr. Ramsay Spillman, 115 East 61st St., New York City. Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

NORTH CAROLINA ROENTGEN RAY SOCIETY
Secretary, Dr. Major Fleming, Rocky Mount, N. C.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

nual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

North Dakota Radiological Society
Secretary, Dr. L. A. Nash, St. John's Hospital, Fargo. Meetings held by announcement.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

Ohio Radiological Society
Secretary, Dr. Henry Snow, 1061 Reibold Bldg., Dayton, Ohio. Meets during annual meeting of Ohio State Medical Association.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport.

Philadelphia Roentgen Ray Society
Secretary, Dr. C. L. Stewart, Jefferson Hospital, Meetings first Thursday of each month, October to May, at at 8:00 p.m., in Thomson Hall, College of Physicians, 21 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. L. M. J. Freedman, 4800 Friendship Ave. Meets 6:30 p.m. at The Ruskin on second Wednesday, each month, October to May inclusive.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Murray P. George, Strong Memorial Hospital. Meets monthly on third Monday from October to May, inclusive, 8 p.m. at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary Dr. A. M. Popma, 220 N. First St., Boise, Idaho.

St. Louis Society of Radiologists
Secretary, Dr. Edwin C. Ernst, Beaumont Medical Building, St. Louis, Mo. Meets fourth Wednesday of each month, except June, July, August, and September, at a place designated by the president.

San Diego Roentgen Society
Secretary, Dr. Henry L. Jaffe, Naval Hospital, Balboa Park, San Diego, Calif. Meets monthly on first Wednesday at dinner.

San Francisco Radiological Society
Secretary, Dr. Carlton L. Ould, University of California Hospital, San Francisco 22. Meets monthly on the third Thursday at 7:45 p.m., first six months of the year at Lane Hall, Stanford University Hospital, and second six months at Toland Hall, University of California Hospital.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 p.m., September to May inclusive.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, 707 Walnut St., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. R. P. O'Bannon, 650 Fifth Ave., Fort Worth 4, Texas. Next meeting, Dallas, Texas, Monday, January 14, 1946.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 p.m. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 p.m., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. E. L. Flanagan, 116 E. Franklin St., Richmond, Va. Meets annually in October.

Washington State Radiological Society
Secretary, Dr. Thomas Carlile, 1115 Terry St., Seattle. Meets fourth Monday each month, October through May, College Club, Seattle.

X-ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly, third Thursday evening.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Medical Members' meeting held monthly on third Friday at 2:30 p.m. and Ordinary Meeting at same time on following Saturday, October to May, 32 Welbeck St., London, W.1.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month at 4:45 p.m. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. J. W. McKay, 1620 Cedar Ave., Montreal, P. Q.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

South America

Sociedad Argentina de Radiologia
Secretary, Dr. Guido Gotta, Buenos Aires, Argentina. Meetings are held monthly.

Sociedad Peruana de Radiologia
Secretary, Dr. Victor Giannoni, Apartado, 2306, Lima, Peru. Meetings held monthly except during January, February and March, at the Asociación Médica Peruana "Daniel A. Carrión, Villalta 218, Lima.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. Babaiantz, Geneva. *Secretary* for German language, Dr. Max Hopf, Effingerstrasse 49, Bern. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad: USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 p.m.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

BOOK REVIEW

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

Dr. W. C. Röntgen. By Otto Glasser, Cleveland Clinic Foundation. Cloth. Price, $4.50. Pp. 169, with illustrations. Springfield, Illinois: Charles C Thomas, 1945.

In this issue of the American Journal of Roentgenology and Radium Therapy which commemorates the Fiftieth Anniversary of the discovery of the roentgen ray, it is particularly fitting that a review appear of this recently published book. As Dr. Glasser states in the preface, "The enthusiam that hailed the use of roentgen rays from the publication of Röntgen's first communication has never abated." Thus, as all radiologists join in paying honor to Röntgen, the book has been sponsored by the three leading radiological societies in the United States, the American Roentgen Ray Society, the Radiological Society of North America and the American College of Radiology.

Dr. Glasser among his many other activities has done an enormous amount of research on the life and work of Röntgen and he is without doubt the outstanding authority on the discoverer of the roentgen ray. In his previous book "Wilhelm Conrad Röntgen and the History of the Roentgen Rays" and in the chapter on "Wilhelm Conrad Röntgen and the Discovery of the Roentgen Rays" published in The Science of Radiology, Dr. Glasser has given many of the details connected with Röntgen's life and the facts leading up to the discovery of the rays as well as the event itself.

Since the year 1945 is the one hundredth anniversary of Röntgen's birth—he was born on March 27, 1845—as well as the fiftieth anniversary of the discovery of the roentgen ray, it seemed an opportune time to publish this additional small volume. It includes some of the material which Dr. Glasser has already published but it also contains new material unearthed by the author in his constant research on his favorite subject. It gives in a compact form the story of Röntgen's life and a new translation of the three communications dealing with the discovery of the roentgen ray—"On a New Kind of Rays" (preliminary communication), December 28, 1895; "On a New Kind of Rays" (second communication), March 9, 1896, and "Further Observations on the Properties of X-Rays" (third communication), March 10, 1897.

There is also given a list of the scientific papers of Röntgen as well as a chronology of his life. The volume has been attractively printed and bound. It offers easy access to the main events of Röntgen's life and the discovery of the roentgen ray and is a book which every radiologist will wish to include in his library.

Ruth Bigelow

INDEX TO ABSTRACTS

ROENTGEN DIAGNOSIS

ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

NECK AND CHEST

Shapiro, M. J., and Keys, Ancel. The prognosis of untreated patent ductus arteriosus and the results of surgical intervention. *Am. J. M. Sc.*, August 1943, *206*, 174–183.

This study was made to learn what could be expected in regard to longevity and cause of death in untreated cases of patent ductus arteriosus and to examine the records of surgery to date. The authors found it necessary to review the entire medical literature and have analyzed all the cases of patent ductus arteriosus in adults from which postmortem examinations have been reported. Eighty per cent of such patients eventually succumb to their cardiac lesion. Those patients who were alive at seventeen years of age averaged thirty-five years of age at death. At least 40 per cent of these patients died of subacute bacterial endarteritis and most of the remainder died of congestive cardiac failure. Spontaneous rupture of the pulmonary artery or the ductus occurred in a few cases.

Through personal correspondence with individual surgeons and internists the authors found that 140 patients had been operated on by a total of 25 surgical teams. Of these cases 107 were uncomplicated while operation was performed on 33 patients in the presence of subacute bacterial endarteritis. In the 107 uninfected cases, 81 operations were completely successful. Of the 33 patients who were operated on in the presence of subacute bacterial endarteritis 20 resulted in apparent complete success, i.e., the blood cultures became sterile and the patient's general condition improved markedly. Errors in diagnosis were made in only 2 instances in the entire group of 140 patients.

The authors conclude that surgery is advisable in the great majority of patients with patent ductus arteriosus with, or without, subacute bacterial endarteritis. In the latter case surgery affords more than a forlorn hope. The uninfected patient cannot expect a normal life span without surgery and is likely to develop subacute bacterial endarteritis at any time in spite of present apparent well being.—*J. J. McCort.*

Brumfiel, Daniel M. Cardiac symptoms in persons with distortion of the mediastinum due to pulmonary tuberculosis. *Am. Rev. Tuberc.*, March, 1943, *47*, 231–252.

This article is a sequel to one published by the author in 1933. It pertains to a study of 38 patients in whom distortion of mediastinal structures was found in conjunction with pulmonary tuberculosis, and cardiac symptoms. None of the group had organic cardiovascular disease.

This study supports the author's earlier contention and the observations of others that distortions of the mediastinal structures *per se* may give rise to cardiac symptoms. Reference is made to the studies of Beck which indicated that "direct traction in the long axis of the heart or simple lateral displacement produced no maleffects, but rotation of the organ on its vertical axis or angulation on the axis of its anchorage at once altered both rate and rhythm."

Such changes have been noted following pneumothorax.

Other studies have indicated that mere stimulation of the sympathetics may cause tachycardia and extrasystoles. The author emphasizes that marked displacement of the superior mediastinum should be particularly productive of this type of circumstance—alleviated by small doses of mild sedatives.

One of the cases manifested cardiac extrasystoles and congestive failure and roentgen evidence of displacement of the arch of the aorta to the left and downward—with inevitable stretching of the left recurrent laryngeal nerve. Besides considering deviations of the arch of the aorta, one should consider deviations of the pulmonary arteries and the veins. The venae cavae are especially susceptable to angulations and thereby, alterations of blood flow—leading to anoxemia and dyspnea and myocardial embarrassment.

These changes may lead to pulmonary hypertension and right heart failure.

Deformities of the thoracic cage may impose derangements of the thoracic viscera.

Electrocardiographic findings were not especially significant; they were noticeable in only 3 of 12 cases where there appeared to be rotation (these showed right axis deviation). One case showed prolongation of the P-R interval to 0.22 second.

Estimates of prognosis seemed to be unreliable. Treatment was considered in terms of prevention, nonsurgical and surgical. In cases of fibrosis, contraction, and cavities, early thoracoplasty was performed. The ultimate deviations of the viscera following pneumothorax were carefully watched with consideration of later requirements of thoracoplasty or phrenic nerve paralysis. Systematic deep breathing exercises were applied in some cases.—*A. A. de Lorimier.*

ABDOMEN

Freedman, Eugene, Glenn, Paul M., and Laipply, Thomas C. Chronic gastritis simulating gastric carcinoma. *Arch. Int. Med.*, Jan., 1943, *71*, 23–37.

Over a period of three years the authors have encountered 5 cases in which the roentgen and gastroscopic appearance of localized, chronic hypertrophic gastritis simulated carcinoma of the stomach. The difficulties in diagnosis presented by these cases was such that carcinoma could not be excluded before an exploratory laparotomy was done. In 3 of the cases the true nature of the lesion did not become apparent until histopathologic examination of the resected specimen was made.

While the roentgen appearance of generalized hypertrophic gastritis can often be recognized, the localized forms are frequently difficult to differentiate from carcinoma. Even gastroscopically the differentiation between a localized inflammatory infiltration and one which is neoplastic cannot always be made.

Chronic gastritis if localized is not necessarily limited to the pyloric portion of the stomach. One of the authors' cases demonstrates that it may be situated on the side of the greater curvature. In 2 other cases it involved only the cardiac portion of the stomach. In 3 of the cases there was rigidity of the wall with absence of peristaltic waves with marked deformity of the contour. In 1 case it caused pyloric obstruction. The authors state that if the wide and irregularly arranged linear or polypoid rugae are associated with defects of contour, the differentiation between gastritis and carcinoma may be extremely difficult, indeed impossible. In certain instances repeated examinations at short intervals may show some regression in the changes favoring gastritis. In order to avoid diagnostic errors a roentgenologist must be conscious of the thick wall and in certain instances should report the possibility of this less serious disease.

Chronic gastritis is of importance because of its possible relation to gastric carcinoma. Patients with this condition should be carefully followed up with repeated roentgen and gastroscopic examinations to discover, if possible, gastric carcinoma in its early stage and thus increase the percentage of surgical cures of carcinoma of the stomach.—*J. J. McCort.*

Kantor, John L. Roentgenology of the digestive tract in the tuberculous. *Am. Rev. Tuberc.*, May, 1943, *47*, 484–492.

Intrinsic tuberculous lesions of the esophagus are rare, though occasional instances of nonspecific ulceration were found, wherein the tuberculous etiology was identified at autopsy. Mediastinal adhesions due to tuberculosis may be responsible for dysphagia.

Likewise, tuberculous lesions of the stomach are rare. Good has reported an instance of 0.34 per cent among unselected autopsies at the Mayo Clinic. Kantor has identified only 2 such cases in the past twenty-five years. In none of these was the diagnosis accomplished before death.

When the lacteal drainage of the small intestine is damaged (as by a tuberculous involvement of the mesenteric lymphatics), fat absorption may be impaired and steatorrhea may result. The findings may be the same as where there is defective fat splitting; the same as in sprue, celiac disease, lymphosarcoma of the intestine or of the mesenteric lymphatics, etc. These conditions may be featured by the "moulage sign"—the appearance of an ironing out of the valvulae conniventes (of the loops of the jejunum and occasionally even in the duodenum). It may be necessary to study the passage of barium repeatedly over a period of three to nine hours after its ingestion in order to identify this feature. Viewings or roentgenography should be accomplished every fifteen minutes in the beginning of the study and

every one to two hours when the ilium is being traversed.

Tuberculous ulcers in the intestines are chiefly located in the ileocecal region—according to Matz: cecum 52 per cent, ilium 39 per cent, ascending colon 32 per cent, ileocecal valve 15 per cent, descending colon 11 per cent, jejunum 8 per cent, appendix 7 per cent, duodenum 6 per cent, rectum 4 per cent, and sigmoid 3 per cent. Tuberculosis of the peritoneum was found in 8.5 per cent.

The author bemoans the fact that proper diagnosis of tuberculous lesions in the upper portion of the tract is usually lacking, prior to death. He attributes this mainly to failure to consider the possibilities in the tuberculous patient. He emphasizes the importance of indirect signs—increased irritability, spasms, stasis, and increased transport beyond the site of a lesion. However, even with substantial evidence, he advises the roentgenologist to resort to the expression "probable tuberculosis," instead of attempting more precise diagnoses. Errors in positive diagnosis are too likely to cause lack of confidence in the roentgen procedure.

Some of the lesions may be manifested by ulcerations; others by deformity, narrowing and irregularity of the lumen (such as due to a tuberculoma).

The most important conditions from which intestinal tuberculosis should be distinguished are the unstable colon, idiopathic ulcerative colitis, cancer, and regional ileitis.—*A. A. de Lorimier.*

SKELETAL SYSTEM

Yaskin, Joseph C., and Tornay, Anthony S. Protruded intervertebral disk and hypertrophied ligamentum flavum. Criteria for diagnosis and indications for operation. *Am. J. M. Sc.*, August, 1943, *206*, 227–233.

Fifty verified cases were studied each of which was personally examined by one of the authors and many by both. The important findings were as follows: The condition is considerably more common in the male than in the female and may occur at any age, but the average age is 39.6 years. In more than half of the cases there was a history of some trauma, as a rule slight. The average duration of symptoms was 4.3 years. Intermissions were observed in 32 cases (varying from days to many years). The initial symptom in the majority of cases was located in the back, usually in the middle and paravertebral portions of the back. The pain is usually deep, unaccompanied by nerve or superficial tenderness and always aggravated by one or more of the several factors such as bending, sneezing or coughing, lifting, etc. Of the 50 cases 42 had a major disability, i.e., were unable to pursue their work and required sedatives and some narcotics. As regards contrast media studies, both air and lipiodol were used. With a few rare exceptions the air myelogram is thought to be a reliable diagnostic procedure. Air studies are unsatisfactory in the examination of lesion between L5 and S1 and often in the cervical swelling of the spinal cord. Of the 42 lipiodol studies, 3 were negative; 2 of these were found to have discs at operation and 1 was negative at operation. Of the 9 air studies 2 had both oil and air (one negative on roentgen study had a disc at L4 and L5).

The analysis of the 50 cases indicates recovery in 36 cases, improvement in 6 cases and failure in 8 cases. These were operated on within the last three and one-half years and the end-result cannot be accurately estimated as yet. It is possible that some cases now apparently recovered may have to be otherwise classified in the future.

After considering the various factors the authors feel that no case in which the diagnosis is reasonably certain should be regarded as a desirable operative subject unless: (1) previous adequate orthopedic and other treatment was afforded for a reasonable time (three to six months) without appreciable improvement in the disability; (2) the existence of moderate to major disability is present; (3) frequently recurrent major disability or recurrent moderate disability for considerable periods is present.—*J. J. McCort.*

Opazo, Luis. Radiodiagnóstico de las afecciones de la columna vertebral. (Roentgen diagnosis of diseases of the spinal column.) *Radiología*, Sept.-Dec., 1943, *6*, 199–209.

In making a thorough examination of the spinal column it is necessary to make not only the routine anteroposterior and lateral views but also oblique views and sometimes to resort to stereoscopy and planigraphy and often to make myelograms with air, oxygen or lipiodol.

As lesions visible roentgenologically do not appear until quite late in these diseases a careful study of the history and thorough clinical

examination must also be made.

Tuberculosis of the spine is very frequent; it begins in the vertebrae and extends secondarily to the intervertebral discs, resulting in typical Pott's disease, which is most frequent in the dorsolumbar column and next in the lumbar column alone. Bone abscesses develop, followed by nervous disturbances. The abscesses may become calcified.

Degenerative diseases of the spinal column may originate in the vertebrae or intervertebral discs. The former group may be traumatic in origin or may be due to senile decalcification of the column of an osteomalacic type, ending in fracture of the vertebra without any direct injury. Three cases of this type are described.

The degenerative diseases beginning in the intervertebral discs may lead to calcification of the disc which is shown on the lateral roentgenogram. But the most interesting of these diseases of the discs are those that lead to herniation of the nucleus pulposus; these are the only ones that can be treated surgically and they are also interesting clinically as they cause serious subjective symptoms due to compression of the intraspinal nerves.—*Audrey G. Morgan.*

Toledo Henderson, Anibal. Radio-diagnóstico de las hernias del núcleo-pulposo. (Roentgen diagnosis of hernias of the nucleus pulposus.) *Radiología*, Sept.-Dec., 1943, *6*, 235–241.

The author makes a study of hernia of the nucleus pulposus into the spinal canal, a condition that is quite frequent but comparatively little known. It is caused by force acting on the spinal column when the patient is bending over. Eighty-eight per cent of the cases of hernia of the nucleus pulposus are seen in the intervertebral discs of the lumbar region, most of them in the last two lumbar vertebrae. The remaining 12 per cent are distributed almost equally between the cervical and dorsal columns. The majority of cases are in men and occur around the age of forty.

The predominant symptom is pain, due to pressure on the nerve roots at their origin. A very large percentage of sciaticas are caused by these hernias. Treatment is surgical.

Diagnosis can be made by myelography with Lafay's heavy lipiodol. The hernia can be localized accurately in this way. After the hernia has been localized by roentgenoscopy, roentgenograms should be made in the anteroposterior and lateral positions. Heavy lipiodol does not have any bad effects if given with the proper technique and removed quickly from the spinal canal. The technique of the examination is reported in detail and illustrative roentgenograms are given, together with the histories of a number of cases.—*Audrey G. Morgan.*

Weber, Harry M. The present status of contrast myelography. *Am. J. M. Sc.*, Nov., 1943, *206*, 687–694.

This article constitutes a review of the literature up to November, 1944. From this review the author draws the following conclusions: 1. A completely satisfactory medium for contrast myelography has not yet been discovered. 2. Lipiodol yields very accurate results. It allows the examination of the entire canal. The roentgenoscopic examination can be repeated later if desired and it will not only localize the lesion but many times will suggest the type of lesion present. On the other hand, lipiodol may cause some irritation of the meninges, its removal is difficult, and the medicolegal aspect of its use must always be considered. 3. Air myelography has limited but definite value, mostly for the examination of the lumbar region to detect protruded intervertebral discs. 4. The clinical and neurological picture is most important in the diagnosis of protruded intervertebral discs. Contrast myelography has value only when the findings are compatible with the clinical and neurologic impression.

(At the time this paper was written pantopaque had just appeared on the market consequently there were no articles available for review concerning it. However, since this paper was published a number of reports have appeared in the medical literature attesting to the superiority of pantopaque over previously used media for contrast myelography.)—*J. J. McCort.*

Riera Bauza, Melchor. Estudio sobre algunas enfermedades no infecciosas de la columna vertebral. (Study of some non-infectious diseases of the spinal column.) *Radiología*, Sept.-Dec., 1943, *6*, 261–268.

In order to understand certain pathological roentgen images in the spinal column, it is necessary to know the normal pictures of its normal embryological and later development.

These are described and they, as well as the diseases discussed, illustrated with roentgenograms.

Schmorl's nodules, or hernia of the nucleus pulposus, are described. They are an important sign in Scheuermann's disease or juvenile kyphosis. They are often attributed to trauma but Schmorl thinks the daily demands on the spinal column are sufficient to produce them. This disease appears generally between the ages of eleven and seventeen, affects the dorsal region chiefly and causes fibrous rigidity of the affected segment.

The commonest of the degenerative diseases of the spinal column is deforming spondylarthrosis which is characterized by the presence of osteophytes, which may form bridges between the vertebrae. Arthrotic lesions are said to occur in 80 per cent of men and 60 per cent of women more than fifty years of age. The clinical importance of the disease is slight. It causes pain in only about 10 to 20 per cent of cases; limitation of movement was the most important symptom in half of 20 cases examined. As a rule it does not cause any nerve lesions.

Baastrup in 1938 described osteoarthrosis of the spinous processes as the cause of certain forms of lumbago; this is known as Baastrup's disease. Degeneration of the intervertebral discs may cause pain resembling that of lumbago or sciatica.

A brief discussion is given of spondylolysis, spondylolisthesis and osteoporosis of the vertebrae. Senile kyphosis is a result of generalized osteoporosis of the spinal column—*Audrey G. Morgan.*

DI RIENZO, S. La espondilitis brucelósica. (Spondylitis in Brucella infection.) *Radiología*, Sept.-Dec., 1943, *6*, 171–198.

Involvement of the spine is very frequent in Malta fever, or infection with *Brucella melitensis*. The figures given by different authors vary greatly—from 20 to 75 per cent—because it is only in recent years that it has been possible to detect the lesions in an early stage. The disease affects not only the bodies of the vertebrae but also the soft parts—cord, meninges, nerves, intervertebral discs and ligaments.

When the disease becomes localized in the spine it causes pain and contractures. The pain varies greatly in severity from a mere pin-prick to the most intense and agonizing pain. The intensity of the pain is not related to the degree of involvement of the vertebrae. Contracture also is variable but it occurs in the most affected segment of the spine. Sometimes it is so great as to cause rigidity of the trunk and prevent even the slightest degree of flexion, extension or rotation while sometimes it is limited to a single muscle group. The vertebral injury does not cause any marked rise of temperature.

The injury of the vertebrae may cause abscesses resembling those of Pott's disease, which may appear on the surface of the body at a distance from the spinal injury. There is no parallelism either between the appearance of abscesses and the severity of the spinal injury. The development of the abscesses may cause a peritoneal syndrome with paralysis of the intestine and retention of its contents, nausea and vomiting, rapid pulse, hypotension and fainting.

The diagnosis of spinal injury may be suggested by the clinical symptoms but can only be made definitely by roentgen examination. Before examining the lumbar column the intestinal contents must be rendered uniform by the evacuation of gas and fecal matter with a cathartic—not by enema—and stimulation of intestinal peristalsis. A correct diagnosis can only be made with a lateral view. Both right and left views should be made and when a series of roentgenograms is made they should be marked right or left. Generators of high efficiency and tubes with a minimum focal spot must be used. Tubes with a rotating anode are almost necessary. The lesions shown by roentgen examination may include osteoporosis, segmental or generalized, hyperostosis in the form of parrot beaks or bone bridges, caries of various degrees and localizations, deformities of the discs which may extend even to total disappearance, and abscesses of the vertebrae.

Prognosis is serious, not only on account of the spinal injury but of the general infection. The disease is an occupational one which may be contracted in handling hides, working in dairies, making cheese, etc. It must be differentiated from other forms of spondylitis which are not occupational and the medicolegal questions involved should be understood.—*Audrey G. Morgan.*

PURRIEL, PABLO, RISSO, R., and ESPASANDIN, J. Localización de la brucelosis en la columna vertebral. (Localization of brucellosis in the spinal column.) *Radiología*, Sept.-Dec., 1943, *6*, 243–260.

The authors made a study of brucellosis of the spinal column based on 35 cases. Their cases were all in men. In general the statistics show a proportion of 8 men to 1 woman. The condition is found most frequently in the dorsolumbar column and rarely in the cervical column. They think the localization is determined by the amount of bone marrow in the affected vertebrae. Formerly brucellosis of the spinal column was thought to be rare but this was because the lesions visible roentgenologically do not appear until the chronic stage of the disease. The authors' 35 cases constituted 62 per cent of the total number of cases of brucellosis examined; they made a systematic roentgen study of the spinal column in all cases of brucellosis seen. There were no abscesses of the vertebrae in their cases, probably due to the fact that they were caused by *B. abortus* rather than *B. melitensis*.

The clinical symptoms are pain and sweating in the acute stage and in the chronic stage increasing localization of the pain in a definite segment of the spinal column with limitation of movement of the column, especially flexion. The pain does not stop on rest, which is a differential point from Pott's disease. Contracture of the paravertebral muscles also takes place, which helps to bring about rigidity of the spine.

The roentgenogram shows areas of decalcification and areas of condensation in the vertebrae. The process begins in the lamina of the vertebrae and when they are eroded hernia of the nucleus pulposus may take place. The hyperostosis may lead to the formation of parrot beaks and bridges of bone between the vertebrae. Decalcification may lead to flattening and finally breaking down of the vertebrae. Many roentgenograms are given showing the various changes in form of the vertebrae caused by the disease. These are not specific, however, and may be caused by other inflammatory diseases of the spinal column. Diagnosis cannot be based on roentgen examination alone but must include a study of the patient's occupational history and of the clinical condition, particularly of a history of a characteristic brucellosis fever in the early stages. The specific biological reactions are important in diagnosis. Intradermal injection of a suspension of dead *Brucella* causes an intense general and local reaction.—*Audrey G. Morgan.*

Ottolenghi, Carlos E. Sobre el diagnóstico de las lesions vertebrales por la biopsia por aspiración. (Diagnosis of vertebral lesions by aspiration biopsy.) *Radiología,* Sept.-Dec., 1943, *6,* 288–291.

There are diseases of the spinal column in which diagnosis either by clinical or roentgen examination is difficult or impossible. As surgical biopsy of the vertebrae is not advisable the author recommends in such cases the use of aspiration for obtaining biopsy material. He has devised an instrument for puncture and aspiration. This instrument and the technique of its use are illustrated by photographs. The material obtained in the aspirating syringe is placed in physiological solution and subjected to histological and bacteriological examination. He has practiced aspiration biopsy in 60 cases without having seen any ill effects from it and the information obtained was extremely useful in diagnosis.—*Audrey G. Morgan.*

Corsellas, M. M. Tumores malignos primitivos del raquis. (Primary malignant tumors of the spinal column.) *Radiología,* Sept.-Dec., 1943, *6,* 279–287.

Primary tumors of bone are rarely localized in the vertebrae. Among the 263 cases of bone tumor studied by the authors only 7 were in the spinal column, or 2.65 per cent; 3 of these were osteogenic sarcoma, 2 Ewing's sarcoma and 1 a plasmocytoma.

The roentgen images of osteogenic sarcoma, Ewing's sarcoma, myeloma and chordoma are described and illustrated with roentgenograms and photomicrographs of the histopathological findings are given.

Osteogenic sarcoma may be osteolytic or osteoplastic. The intervertebral disc is generally not affected. Late in the disease the tumor may break down the vertebra and invade the surrounding tissues, giving pictures that resemble those of Pott's disease. Pathological fractures are frequently seen in the last stages of these tumors. Early diagnosis is difficult, however, and sometimes paraplegia or paresthesias develop before tumor is suspected and roentgen examination made. The indemnity of the intervertebral disc is a point of differentiation from Pott's disease and other forms of spondylitis, such as those of typhoid fever, Malta fever, staphylococcus spondylitis, etc.

A roentgen diagnosis can be made of malignant tumor of the spinal column but never of its nature. Microscopic diagnosis is often difficult also.—*Audrey G. Morgan.*

Daza, Felix. Radio-diagnóstico del cáncer de la columna vertebral. (Roentgen diagnosis of cancer of the spinal column.) *Radiología*, Sept.-Dec., 1943, *6*, 211–219.

The author discusses cancer of the spinal column based on cases seen at the Central Laboratory of Radiography of the Salvador Hospital in Santiago de Chile. Roentgenograms were made of the spinal column in 1,699 cases, 853 of which proved to be pathological. Among these 853 cases 42, or 4.9 per cent, were cancer of the spinal column. These cancers may be of the osteolytic, osteosclerotic or mixed types. The osteolytic types are characterized by destruction of bone. In the beginning, the shape and size of the vertebra are preserved but later it yields to pressure and breaks down. This process may be sudden or gradual. The osteosclerotic form, in which the bone is sclerotic and eburnated, is almost always secondary to cancer of the prostate. The vertebrae do not break down as the sclerosis gives increased resistance to pressure.

Primary cancer of the spinal column is extremely rare. In the author's material there were only 2 cases, both sarcomas. Metastatic cancers invade the spinal column by way of the blood. They are always secondary to carcinoma; sarcoma does not produce metastases in the spine.

The osteosclerotic form must be differentiated from Albers-Schönberg's disease, or osteosclerosis fragilis, in which the roentgen appearance is similar but which differs in extent and localization of the process. The osteolytic form must be differentiated from tuberculous spondylitis and fracture. In Pott's disease the affected vertebrae fuse completely and the interline disappears, while in cancer the outlines of the vertebrae can always be seen. The differentiation from fracture must be based on the history and clinical examination as differentiation is not always possible from the roentgenogram.

The article is freely illustrated with roentgenograms of the different types of tumors studied.—*Audrey G. Morgan.*

Caminha, Nicola C. Estudo radiológico dos tumores, sem o emprego de meios de contraste. (Roentgen study of tumors without the use of contrast media.) *Radiología*, Sept.-Dec., 1943, *6*, 220–234.

The roentgen literature in general says that roentgenography of tumors of the spinal canal is negative. The author believes this is a mistake and these tumors often cause changes which are visible on roentgen examination without the use of contrast media. He gives a table from Elsberg's work showing the different histopathologic types of tumors found in the spinal canal and their localization in the different segments of the vertebral column. He briefly reviews the appearance and clinical signs of the chief types of tumor found in the spinal canal, the meningiomas, neurinomas, sarcomas, ependymomas, idiopathic cysts and lipomas.

A description is given of the roentgen changes that are seen in the bodies of the vertebrae, the spinous processes and pedicles. He then studies the Elsberg-Dyke "rachimetric curve." He describes the method of making it and the changes found in the curve in intraspinal tumors, syringomyelia and meningocele. He thinks it is of great diagnostic value and may sometimes even be used as a substitute for myelography.

The article is freely illustrated with roentgenograms and Elsberg-Dyke curves of cases.—*Audrey G. Morgan.*

Caro, David L., and Ingber, Edmundo. Valor clínico de la exploración radiológica de la articulación sacro-ilíaca. (Clinical value of roentgen examination of the sacroiliac joint.) *Radiología*, Sept.-Dec., 1943, *6*, 269–278.

In order to make a complete and correct roentgen examination of the complicated sacroiliac region, the patient should be placed symmetrically with reference to the film and the tube focus; anteroposterior, posteroanterior and oblique projections with different degrees of rotation around 45° should be used. The central ray should be directed on the segment of the joint that is to be studied. Routine interpretation should be avoided and a very careful study made of each individual case.

The anatomy of the joint is described and diagrammatic sketches of its constituent parts given; also a diagrammatic drawing of the roentgen image of the joint.

The authors conclude from their experience that lesions of the sacroiliac joint precede inflammatory and degenerative lesions of the spinal column; that they are an early phase of the latter and the only stage that can really be cured, and therefore they deserve much more careful attention on the part of roentgenologists than has heretofore been given them.—*Audrey G. Morgan.*

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